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A SHORT COURSE

IN

CHEMISTRY,

BASED ON THE

EXPERIMENTAL METHOD.

BY

THOMAS R. BAKER, PH. D.,

PROFESSOR OF PHYSICS AND CHEMISTRY, STATE NORMAL SCHOOL, MILLERSVILLE, PA.; AND AUTHOR OF ELEMENTS OF NATURAL PHILOSOPHY.

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1883.

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PREFACE.

THE study of Chemistry is valuable for the reason that the science directs attention to many important facts and phenomena of nature and contributes greatly to the comforts and conveniences of life. It is also valuable as a means of education, affording in a high degree—if the subject be rightly pursued—the special culture needed for general scientific work.

This volume is designed for students beginning the subject of chemistry. It presents the leading facts and principles of the science, including the results of the most recent chemical study and investigation, and may therefore serve either for class instruction or for private students. The arrangement of the subject matter and the order of discussion are natural and logical, and will enable the student easily to study the subject and readily to remember what he has learned. To render the study more intelligible, the general subject is preceded by a discussion of chemical nomenclature and notation, and of the more important chemical terms and processes. To facilitate the experimental work directed by the book, the experiments are described in careful detail, and are generally preceded by an enumeration of the apparatus and material needed in performing them.

In the preparation of the book the author has freely consulted the admirable works of Bloxam, Fowne, Cooke, Pinner and others. He acknowledges his indebtedness to Prof. A. A. Breneman for valuable assistance in the classification of the subject, etc., and to Prof. E. Oram Lyte, for valuable suggestions relating to the typography of the work. His thanks are also due to Messrs. Bullock & Crenshaw, 528 Arch St., Philadelphia, and to Messrs. Queen & Co., 924 Chestnut St., Philadelphia, for cuts of apparatus described in the appendix.

STATE NORMAL SCHOOL,
MILLERSVILLE, PA., *July*, 1883.

SUGGESTIONS TO TEACHERS AND PUPILS.

THIS book is designed to combine both theoretical and experimental instruction. An experiment should first be described by the pupil and then performed before the class, either by the teacher or by a pupil under the direction of the teacher. Or the entire lesson may be recited, and then the pupils, provided with their own apparatus and places at a laboratory table, be assigned the experiments to perform for themselves. They may be assigned the same experiment or different experiments, according to the number contained in the lesson. The book may be used in the class-room without performing the experiments, but this plan is not a good one. Or it may be used as a laboratory text-book, the student carefully reading the theoretical part.

If the teacher is not provided with a chemical laboratory, there should be a room set apart, near the class-room if possible, for chemical manipulation. This room should be capable of easy and thorough ventilation, and should contain a chimney or flue to carry off offensive and noxious gases and vapors. If regular laboratory tables (which are large tables supporting shelves for reagents, etc., with drawers and cupboards underneath) cannot be obtained, almost any tables will answer the purpose.

The pupil should keep his apparatus and his part of the table clean, and learn to work neatly. He should carefully observe the results of experiments and clearly understand how these results establish the facts stated. If an experiment fails, it should be tried again, and the cause of the failure carefully studied.

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A SHORT COURSE
IN
CHEMISTRY.

INTRODUCTION.

Historical Sketch.

IT is supposed that the Egyptians possessed the most chemical knowledge of any nation of antiquity. They could preserve the bodies of their dead, were skilled in the art of dyeing, and could prepare many chemical products, among which were various medicines, soap, and glass. It is probable that the term chemistry is derived from the ancient name for Egypt, *Chemia.*

The Chinese, at a very early date, were acquainted with the preparation of gunpowder, the making of paper, etc. The Greeks and Romans gained most of their chemical knowledge from the Egyptians, and made little advancement in the science. Aristotle held that there are four elementary substances, fire, air, earth, and water.

In the Middle Ages the impression prevailed that there existed a substance called the "philosopher's stone," which could change all things into gold, and this substance was eagerly sought after by the chemists of the time, called *alchemists.* The alchemist's work embraced also the search for the "elixir of life" by which existence could be indefinitely prolonged.

The discovery of aqua regia, the solvent of gold, the explanation of the action of acids and bases, and the investigation of the causes of chemical action and the chemical relations of

heat and light, were important steps in the direction of modern chemistry, which may be said to have originated toward the end of the 17th century. It was then that oxygen was discovered, the chemical knowledge of the time systematized by Lavoisier, and the atomic theory introduced by Dalton. The researches of Davy, Gay Lussac, Faraday, Wöhler, Liebig, and many distinguished men of our own time, have brought the science to its present advanced condition.

Definitions.

Matter is anything that occupies space, as earth, water, air.

Units of Matter.—An *atom* is an ultimate, indivisible portion of matter. The *atomic theory* assumes that all matter is made up of atoms, that the atoms of the same element have a uniform weight, and that the atoms of different elements have different weights. A *molecule* is a combination of atoms. A *mass* is an aggregation of molecules, and the term is applied to the motes in air as well as to rocks and worlds. The term mass is also used to denote the quantity of matter in a body.

A **Substance** is one of the kinds of matter, as gold, wood, oil. *Organic* substances are those that are produced by life; *inorganic* substances are those that are not produced by life. Tallow and wood are organic; iron and water, inorganic.

Properties of Matter.

Physical properties arise from physical changes, which change the form and quality of a substance without destroying its distinctive character. Thus iron may be made into a multitude of useful articles, but its nature is not changed. Ice and steam are only forms of water.

Chemical properties arise from chemical changes which destroy the distinctive character of a substance. Thus the products obtained by decomposing water, oxygen and hydrogen, are entirely unlike water. When limestone is burned, its carbonic acid is driven off and lime is left.

Chemistry *treats of the kinds and properties of matter, and the chemical changes which it undergoes.*

Chemical Elements and Compounds.

A **Chemical Element** or *simple substance* is a substance that cannot be separated into different kinds of matter. Thus iron and sulphur are elements, because they cannot be separated into parts which are not iron and sulphur.

A **Chemical Compound** is a substance formed of elements united chemically; as, water (H and O), sugar (C, H, and O). Compounds are classified as *binary*, composed of *two* elements, *ternary*, composed of *three* elements, etc.

Acids, Bases, and Salts.—The most important ternary compounds are *acids*, *bases*, and *salts*. An *acid* is a compound generally soluble in water and having usually a sour taste. The acids all contain H, generally O, and another element. A *base* is a hydrate (p. 17) which has the power of neutralizing an acid. A *salt* (so named from its resemblance to common salt) is a compound formed by the replacing of the H of an acid by a metal or electro-positive radical. (See the author's *Nat. Phil.*, p. 285.)

A **Radical** is an atom or a group of atoms forming the chief constituent of the molecule of a compound. A *simple* radical is composed of a single atom; a *compound* radical is composed of a group of atoms. The group acts as a single atom.

Analysis and Synthesis.—Chemical analysis is the process of separating a compound into its constituent parts. When the parts are elements, the process is called *ultimate analysis;* when they are compounds, it is called *proximate analysis.* Synthesis is the union of substances to form a new compound.

A **Mixture** is a product formed of substances not united chemically; as, air (O, N, etc.), gunpowder (charcoal, sulphur, saltpetre). The parts of a mixture may be separated by mechanical means; the elements of a compound cannot thus be separated. Thus iron filings and flowers of sulphur, when mixed together, may be separated by means of a magnet, but if the mixture be strongly heated, the ingredients combine chemically and they cannot be thus separated.

TABLE OF THE ELEMENTS.

(S.=symbol; At. Wt.=Atomic Weight. NAMES OF LEAST IMPORTANT ELEMENTS IN ITALICS.)

Name.	*S.*	*At. Wt.*	*Derivation.*	*Discovery.*
Aluminum . . .	Al .	27·0	Lat. *alumen*, alum . . .	Wöhler, 1828.
Antimony (*stibium*)	Sb .	120·0	Arab. *al-ithmidan* . . .	Valentine, 1640?
Arsenic.	As .	75·0	Gr. *arsenicon*	Schroeder, 1694.
Barium	Ba .	137·1	Gr. *baros*, heavy	Davy, 1808.
Bismuth	Bi. .	210.0	Ger. *wesemat*.	Agricola, 1529.
Boron	B . .	11·0	Arab. *burag*, borax . . .	Davy, 1807.
Bromine	Br .	80·0	Gr. *bromos*, stench . . .	Balard, 1826.
Cadmium. . . .	Cd .	112·3	Gr. *cadmia*, calamine . .	Stromeyer, 1817.
Caesium	Cs .	133·0	Lat. *caesius*, blue. . . .	Bunsen, 1860.
Calcium	Ca .	40·0	Lat. *calx*, lime	Davy, 1808.
Carbon.	C . .	12·0	Lat. *carbo*, coal	Ancients.
Cerium	Ce .	141·0	Lat. *Ceres*, a Roman deity.	Berzelius, Hisinger, 1803.
Chlorine	Cl. .	35·5	Gr. *chloros*, green . . .	Scheele, 1774.
Chromium . . .	Cr .	52·2	Gr. *chroma*, color . . .	Vanquelin, 1797.
Cobalt	Co .	58·8	Ger. *kobold*, a goblin . .	Brandt, 1733.
Columbium . . .	Cb .	94·0	*Columbia*, America . . .	Hatchett, 1801.
Copper (*cuprum*) .	Cu .	63·3	Lat. *cyprium*, Cyprus . .	Ancients.
Decipium (?) . .	De .	157·0	Lat. *decipere*, to deceive .	Delafontaine, '78.
Didymium. . . .	D . .	140·0	Gr. *didumos*, double . .	Mosander, 1841.
Erbium	Er .	167·0	*Ytterby* in Sweden . . .	Mosander, 1843.
Fluorine	F . .	19·1	Lat. *fluere*, to flow . . .	Not isolated.
Gallium.	Ga .	70·0	Lat. *Gallia*, France. . .	Boisbaudran, '77.
Glucinum	Gl .	. . .	Gr. *glukus*, sweet. . . .	Vanquelin, 1798.
Gold (*aurum*) . .	Au .	197·0	. . . . .	Ancients,
Holmium (?). . .	Ho .	162·0	*Stockholm*	Cleve, 1879.
Hydrogen. . . .	H . .	1 . .	Gr. *hudor*, water, and *genein*, to produce	Cavendish, 1766.
Indium	In. .	113·7	*Indigo*, a blue dye . . .	Reich, Richter, 1863.
Iodine	I . .	126·8	Gr. *ion*, violet	Courtois, 1811.
Iridium.	Ir. .	192·7	Lat. *iris*, rainbow . . .	Tennant, 1803.
Iron (*ferrum*) . .	Fe .	56·0	. . . . .	Ancients.
Lanthanum . . .	La .	139·0	Gr. *lanthanein*, to conceal.	Mosander, 1841.
Lead (*plumbum*) .	Pb .	206·9	. . . . .	Ancients.
Lithium.	Li. .	7·0	Gr. *lithos*, a stone . . .	Davy, Arvedson, 1818.
Magnesium . . .	Mg .	24·0	*Magnesia*, Asia Minor . .	Bussy, 1830.
Manganese . . .	Mn .	55·0	" " " . .	Galm, 1774.
Mercury (*hydrargyrum*).	Hg .	200·0	Name of Roman deity .	Ancients.
Molybdenum . . .	Mo .	96·0	Gr. *molybdos*, lead . . .	Hjelm, 1782.
Nickel	Ni .	58·6	Ger. *kupfernickel*	Cronstedt, 1751.

Name.	*S.*	*At. Wt.*	*Derivation.*	*Discovery.*
Nitrogen	N . .	14·0	Gr. *nitron*, nitre, and *genein*.	Rutherford, 1772.
Norwegium (?). .	No .	145·9	Norway.	Dahll, 1879.
Osmium	Os .	199·2	Gr. *osme*, odor	Tennant, 1803.
Oxygen	O . .	16·0	Gr. *oxus*, acid, and *genein*.	Priestley, 1774.
Palladium	Pd .	106·6	Gr. *Pallas*, a deity . . .	Wollaston, 1804.
Phosphorus . . .	P . .	31·0	Gr. *phos* and *phero* . . .	Brandt, 1669.
Platinum	Pt .	194·8	Span. *platina*	Wood, 1741.
Potassium (*kalium*)	K . .	39·1	Eng. *pot-ashes*	Davy, 1807.
Rhodium	Rh .	104·4	Gr. *rhodon*, a rose . . .	Wollaston, 1803.
Rubidium	Rb .	85·4	Lat. *rubidus*, red	Bunsen, 1860.
Ruthenum	Ru .	104·4	*Ruthenia*, Russia	Claus, 1845.
Scandium	Sc .	44·0	Scandinavia (?)	Nilson, 1879.
Selenium	Se .	79·2	Gr. *selene*, the moon . .	Berzelius, 1817.
Silicon	Si .	28·0	Lat. *silex*, flint	Berzelius, 1823.
Silver (*argentum*).	Ag .	108·0	. . . . .	Ancients.
Sodium (*natrium*)	Na .	23·0	Lat. *salsola*, soda. . . .	Davy, 1807.
Strontium	Sr. .	87·6	*Strontian*, Scotland . . .	Davy, 1807.
Sulphur	S . .	32·0	Lat. *sulfur*	Ancients.
Tantalum	Ta .	182·0	*Tantalus*, mythol. person.	Ekeberg, 1802.
Tellurium	Te .	128·0	Lat. *tellus*, the earth . .	Klaproth, 1798.
Terbium (?) . . .	Tr .	171·0	Lat. *ter*, third	Mosander, 1843.
Thallium	Tl .	204·1	Gr. *thallos*, a green twig.	Crookes, 1861.
Thorium	Th .	231·4	*Thor*, a Swedish deity .	Berzelius, 1829.
Thulium (?) . . .	Tm .	170·0	Lat. *Thule*	Cleve, 1879.
Tin (*stannum*) . .	Sn .	118·0	. . . . .	Ancients.
Titanium	Ti. .	50·0	*Titans*, mythol. person .	Klaproth, 1791.
Tungsten (*Wolframium*) . . .	Wo .	184·0	Sw. *heavy stone*	De Luyart.
Uranium	Ur .	120·0	Gr. *Ouranos*, heaven. . .	Klaproth, 1789.
Vanadium	V . .	51·3	*Vanadis*, deity	Lefstrom, 1830.
Ytterbium (?) . .	Yb .	173·0	*Ytterby* in Sweden.	
Yttrium	Y . .	91·0	*Ytterby*	Wöhler, 1828.
Zinc	Zn .	65·2	. . . . .	Paracelsus.
Zirconium	Zr .	89·6	Ceylonese, *Zircon* . . .	Berzelius, 1824.

Substances which will generally be designated by their symbols.

Oxygen	O.	Water	H_2O.
Hydrogen	H.	Hydrochloric Acid	HCl.
Nitrogen	N.	Sulphuric Acid	H_2SO_4.
Chlorine	Cl.	Nitric Acid	HNO_3.
Sulphur	S.	Ammonium Hydrate . .	$(NH_4)HO$.
Carbon	C.	Carbon Dioxide (Carbonic Acid)	CO_2.

Chemical Affinity and Chemical Action.

Chemical Affinity or *Chemism*, is the force by means of which elements combine to form chemical compounds; as O and iron to form iron rust. It acts between atoms, and hence at insensible distances. It is variously affected by cohesion, heat, light, and electricity.

Chemical Action is the action due to chemical union and separation. It may be energetic, as in the burning of gunpowder, or quiet, as in the rusting of iron.

Nomenclature and Notation.

Symbols are used in chemistry to represent substances more briefly than they are represented by the name, and also to designate their atomic constitution, the symbol of an element designating a single atom.

Elements.

Names.—The elements which were earliest known retain their old names. Many of those more recently discovered are named from some property; as, chlorine, from its green color, and bromine, from its fetid odor. The names of the recently discovered *metals* end in *um;* as, sodium, potassium.

Symbols.—The initial letter of the Latin name of an element is generally taken as the symbol of the element. When two or more names have the same initial letter, a second letter is added. Thus O is the symbol of oxygen, C of carbon, Ca of calcium, and Cl of chlorine.

General Compounds.

Names.—Chemical compounds have names which designate their ingredients, and generally at least one other name by which they are known in commerce. Thus hydrochloric acid (composed of H and Cl) is also called muriatic acid.

Symbols.—The symbol of a compound is formed of the symbols of its constituent elements, generally arranged in the order in which they occur in the name of the compound. Thus HCl is the symbol of hydrochloric acid.

A small figure on the line at the right of a symbol denotes the number of atoms when more than one are combined. Thus H_2 (read H-two) means two atoms of H. A figure to the left of a symbol or group of symbols, from which it is not separated by a parenthesis, multiplies the symbol or group. Thus 3 H_2O means three molecules of water. A figure outside of a parenthesis multiplies the group or groups within the parenthesis. Thus 2 (NH_4Cl) or $(NH_4Cl)_2$ means two molecules of ammonium chloride.

The results of chemical reactions are expressed by equations. The symbols of the substances to be acted on are placed as the left-hand member and those of the new product or products as the right-hand member of the equation. Thus:

$$CaO + H_2O = CaO_2H_2$$

Lime Water Calcium hydrate.

The term *formula* is sometimes applied to the symbols of a compound. When the symbols are arranged so as to indicate the substances which have combined to produce the compound, they constitute a *rational* formula; when they represent the composition of the compound only, they constitute an *empirical* formula. Thus the rational formula of ordinary phosphoric acid is 3 H_2O,P_2O_5 (H_2O, and phosphoric oxide); the empirical formula is H_3PO_4 (similar in the proportion of the atoms indicated to 3 H_2O,P_2O_5).

Classified Compounds.

Binaries.—The name of a binary is formed from the names of both elements. The first part of the name is that of the most electro-positive element with the termination changed to *ous* or *ic*, the second expressing the larger quantity of the positive element. The second part of the name is that of the most electro-negative element with the termination changed to *ide*. Thus ferrous oxide (FeO), ferric oxide (Fe_2O_3). The latter contains the most O.

Prefixes are also used and are either numeral, as in the term *di*oxide (two atoms of O), or general, as in *per*chloric and

*hypo*chloric, which are used when more than two compounds are formed of two elements.

Ternaries.—In naming the inorganic acids and the bases (hydrates), the terminations *ous* and *ic* are used as in naming binaries. Thus, sulphurous acid, H_2SO_3, sulphuric acid, H_2SO_4, ferrous hydrate, FeH_2O_2, ferric hydrate, $Fe_2H_6O_6$.

In naming the salts the name of the group or class is formed by changing the *ous* terminating the name of the acid to *ite* or the *ic* to *ate*. Thus sulphurous acid forms a sulphite, and sulphuric acid, a sulphate.

Bond and Graphic Symbols.

Bond Symbols are the ordinary symbols with short lines called *bonds*, indicating the quantivalence (p. 15) of the element, radiating from them. Thus: (p. 16).

Monad,	Dyad,	Triad,	Tetrad,	Pentad,	Hexad.
H–	O=	N≡	C≡	–P≡	≡Fe≡

The bonds may have almost any direction, as O=, –O–, O–, O< etc.

When chemical action takes place the bonds are united, each atom having the number by which it is designated. Thus:

		H	H
		H–N–H	H–C–H
			H
H–Cl	H–O–H		
Hydrochloric Acid,	Water,	Ammonia,	Marsh Gas.

Graphic Symbols are diagrams used as symbols. Those devised by Kekulé consist of short dashes, enclosed by curves, to indicate the quantivalence of the atom. Thus H is represented by *one* enclosed dash, O by *two* enclosed dashes, etc.

Laws of Chemical Combination.

Definite Proportions.

A chemical compound always contains the same elements combined in the same proportions. Thus, pure H_2O is composed of 11.11 parts by weight of H to 88.89 parts of O; HCl, 2.74 parts of H to 97.26 of Cl.

Atomic Weights.—The molecule of H_2O consists of two atoms of H and one of O. Hence, referring to the composition of H_2O just given, the O atom must be 16 times as heavy as the H atom. It is also seen that the Cl atom is 35.5 times as heavy as the H atom. The numbers 1, 16, 35.5, are called *atomic weights* (p. 10).

The atomic weights of the elements are therefore the relative weights of their atoms. The absolute weight of the atoms cannot be determined.

The *molecular weight* is equal to the sum of the weights of the atoms in the molecule. Thus the molecular weight of H_2O is 18.

Percentage Composition.—The part which an element forms of a compound is indicated by the ratio of the atomic weight of the element to the molecular weight of the compound. Thus, since the molecular weight of H_2O is 18 ($\overset{H}{2} + \overset{O}{16}$), the H forms $\frac{2}{18}$ or 11.11 per cent., and the O, $\frac{16}{18}$ or 88.89 per cent.

Multiple Proportions.

If more than one compound is formed by the union of two elements, the larger quantities of the combining elements are simple multiples of the smallest quantity. A good illustration of this law is afforded by the compounds of O and N, shown in the following table. The amount of O which is combined in each with 1.75 parts of N, is given.

	N By Weight.	O By Weight.	N By Vol.	O By Vol.
Nitrogen Monoxide, N_2O	1.75	1	2	1
Nitrogen Dioxide, NO	1.75	2	2	2
Nitrogen Trioxide, N_2O_3	1.75	3	2	3
Nitrogen Tetroxide, NO_2	1.75	4	2	4
Nitrogen Pentoxide, N_2O_5	1.75	5	2	5

Quantivalence.

One atom of Cl unites with *one* of H to form HCl; one of O unites with *two* of H to form H_2O; one of N unites with

three of H to form ammonia; one of C unites with *four* of H to form marsh gas. It is thus seen that the different kinds of atoms, Cl, O, etc., require different numbers of H atoms with which to form compounds.

HCl	H_2O	H_3N	H_4N
Hydrochloric Acid.	Water	Ammonia.	Marsh Gas.

One atom of potassium replaces *one* of H in HNO_3 to form potassium nitrate; one of copper replaces *two* of H in H_2SO_4 to form copper sulphate.

$H\|NO_3$, Nitric Acid,	$H_2\|SO_4$, Sulphuric Acid.
$K\|NO_3$, Potassium Nitrate,	$Cu\|SO_4$, Copper Sulphate.

This quantity-combining or quantity-replacing power of an element is called its *quantivalence*, and the H atom is taken as the standard of reference.

It may therefore be stated that *the quantivalence of an element or of a compound radical denotes the number of hydrogen atoms with which one of its atoms can combine or the number of hydrogen atoms which one of its atoms can replace.* Thus the quantivalence of potassium is 1, of oxygen 2, of carbon, 4.

The elements are classified according to their quantivalence as *monads*, *dyads*, *triads*, etc., potassium being a monad, oxygen, a dyad, and carbon, a tetrad.

Volume Relations.

Ampere's Law.—The following, called *Ampere's Law*, is accepted as a fundamental principle of chemistry: *Equal volumes of all gases, under like conditions of temperature and pressure, contain the same number of molecules.*

It is estimated that a litre of any gas contains 10^{24} molecules.

If a given volume of H, for example 1000 molecules, combine with an equal volume of Cl, which, according to Ampere's Law, must contain the same number of molecules, there will be found two volumes of HCl, which will contain 2000 molecules. Since, however, each HCl molecule contains an atom of H and an atom of Cl, the 2000 acid molecules must contain

2000 atoms of each element; but the 2000 atoms of H constitute the original amount of H or 1000 molecules. Hence the H molecule must contain *two* atoms. The Cl molecule must also contain two atoms.

The Law of Volumes.—In the combination of gases or vapors, the volume of the compound (as a gas) formed is sometimes equal to, but generally less than the sum of the volumes of its constituents. The law is *that the volume of a gaseous compound bears a simple ratio to the volumes of its constituents.*

Thus *one* volume of H and *one* of Cl combining form *two* volumes of HCl; *two* of H and *one* of O form *two* of steam; *three* of H and *one* of N form *two* of ammonia. It is seen that in the first example there is *no* contraction of volume, in the second that *three* volumes are condensed into *two*, and in the third that *four* are condensed into *two*.

Specific Volumes.—*The product volume.* It is learned from the examples just given that there are always *two* volumes of the gaseous compound. This doubled volume is called the *normal* or *product volume* of the gas.

The Unit Volume.—The unit volume employed in discussing the volumetric relation of gases and vapors is the volume of one atom of H.

Chemical Terms.

Hydrate.—The term *hydrate* is applied to a class of compounds which may be regarded as formed from H_2O by replacing half of its H by some metallic atom or radical acting as a metal. Thus, H-O-H (water), by exchanging an atom of H for one of K becomes KOH, potassium hydrate.

Alkali.—The term *alkali* is applied to a class of very soluble bases, comprising the hydrates of potassium, sodium, ammonium, etc.

Amorphism.—The term *amorphous* is applied to substances without crystalline form. Thus charcoal, rock salt, and flint, are *amorphous* substances.

Allotropism.—The term *allotropic* is applied to a condition of an element which can have different properties. Thus diamond and charcoal are allotropic forms of C.

Isomerism.—The term *isomeric* is applied to substances having the same composition (so far as analysis can determine) but different properties. Thus, cane sugar and gum arabic, each of which contains C, H, and O, in the same proportions, are isomeric compounds. Isomerism is supposed to be due to a difference in the arrangements of atoms within the molecule.

Catalysis.—The term *catalysis* is applied to a kind of action by which a substance seems to exert a chemical effect without itself changing. Thus, in preparing O from a mixture of potassium chlorate and manganese dioxide (Exp. 63) the latter substance does not change.

Nascent State.—Substances just set free from combination are said to be in a *nascent state.* They are then more active than after they have been some time free. Thus N and H, the constituents of ammonia, do not combine when mixed, but readily combine on being set free together from compounds.

Water of Crystallization.—*Water of crystallization* is a definite amount of H_2O which certain substances take up on crystallizing, and to which they owe their crystalline forms. It may be driven off by heat. Thus the crystals of common alum contain 24 molecules of H_2O. When the substance is heated, the crystalline form is destroyed and the residue is "burnt" alum.

Mother Liquor.—The term *mother liquor* is applied to the liquid in which crystals have formed. It is a saturated solution (p. 20) of the substance which has crystallized.

Effervescence.—Effervescence is the escape of a gas from a liquid in which it is either generated or has been held by pressure, as carbonic acid from dissolving marble or from soda water.

Deliquescence.—*Deliquescence* is the solution of a substance in H_2O which it absorbs from air.

To Show Deliquescence.—*Apparatus.*—Piece of window glass. *Material.*—Small lump of potassium hydrate (KHO).

Experiment 1.—Expose the KHO to air on the glass for half an hour. It will deliquesce.

Efflorescence.—*Efflorescence* is the gradual crumbling of a crystal to powder on exposure to air. It is due to the escape of water of crystallization.

To Show Efflorescence.—*App.*—Piece of window glass. *Mat.*—10 g. of Glauber's salt.

Exp. 2.—Expose the salt to air in a warm place for several hours. It will become opaque and finally crumble. Weigh the powder. Its weight will be only about 5 g.

Reaction.—A *reaction* is the action of chemical agents upon each other. A *reagent* is a substance by which reactions are produced.

Alloy.—An *alloy* is a compound of two or more metals; as brass, consisting of copper and zinc. An *amalgam* is an alloy in which one of the combining metals is mercury.

Chemical Processes.

Solution.

Solution is the disappearance of a substance in a given liquid. The substance is said to be *dissolved* in the liquid, the liquid to be a *solvent* of the substance, and the combined mass of liquid and substance to be a *solution* of the substance. The dissolved substance loses its original physical properties.

To Show Solution.—*App.*—3 large test-tubes. *Mat.*—1 g. each of sugar and starch, 0.3 g. zinc (Zn.), HCl, and H_2O.

Exp. 3.—Put the sugar and 5 c.c. of H_2O in a test-tube and shake the tube. The sugar dissolves in the H_2O. Examine the solution by looking through it toward a good light. It should be as transparent as water.

Exp. 4.—Put the Zn. and 2 c.c. of HCl in a test-tube. The Zn. dissolves in the HCl.

Exp. 5.—Put the starch and 5 c.c. of H_2O in a test-tube, and shake the tube. The starch does not dissolve; it mixes with the H_2O.

Weakening the cohesion among the molecules of a sub-

stance, as by reducing it to powder, or by heating, hastens its solution.

To Show that Pulverization and Heat Hasten Solution.—*App.*—3 large test-tubes, mortar, and lamp. *Mat.*—3 g. sugar in 1 g. portions.

Exp. 6.—Pulverize two of the portions of sugar. Put 10 c.c. of H_2O in each of the tubes and heat the H_2O in one of them to boiling. Then put, as nearly at the same time as possible, the portion not powdered in a tube containing cold H_2O, and the other portions in the other tubes, and shake all the tubes at the same time. It will be seen how greatly solution may be hastened.

A *saturated* solution is produced when a liquid has dissolved all of a substance that it can dissolve.

To Make a Saturated Solution.—*App.*—Large test-tube and lamp. *Mat.*—Sugar and H_2O.

Exp. 7.—Dissolve by heating a little sugar in 2 c.c. of H_2O; add a little more sugar and heat again until the solution is complete. Continue adding sugar and heating until some of the substance remains undissolved. The liquid is a saturated solution.

Crystallization.

Crystallization is the arrangement of the molecules of a substance in regular forms bounded by plane faces. Many substances crystallize in passing from a liquid or a gaseous to a solid state. A hot saturated solution of a crystalline substance generally crystallizes on cooling slowly.

To Show Crystallization.—*App.*—4 test-tubes, 4 watch-glasses (or other shallow vessels), lamp, and piece of clean window-glass. *Mat.*—1 g. alum, 1 g. potassium dichromate, 2 g. saltpetre, 2 g. blue vitriol, 0.2 g. ammonium chloride and H_2O.

Exp. 8.—Dissolve each of the first four substances in 5 c.c. of H_2O and pour the solutions in the watch-glasses. The substances crystallize as the liquids cool.

Exp. 9.—Dissolve the ammonium chloride in a small quantity of H_2O and spread a drop of the solution on the glass. A beautiful crystallization will soon appear.

If the crystals do not form, they may be produced by removing H_2O from the solution by evaporation.

Crystals by Evaporation.—*App.*—Large test-tube, evaporating dish, and lamp. *Mat.*—1 g. blue vitriol and H_2O.

Exp. 10.—Dissolve by heating the vitriol in 10 c.c. of H_2O and allow the solution to cool. The crystals do not form. Reduce the solution by evaporation to one-third of its original bulk, and allow it to cool again. The crystals now form.

PRECIPITATION.

Precipitation is the separation in a solid state, by chemical action, of a substance originally in solution. The solid is said to be *precipitated* and is called a *precipitate.* Precipitates are generally finely divided, but may also be gelatinous, curdy, crystalline, granular, or flocculent.

TO SHOW PRECIPITATION.—*App.*—2 test-tubes. *Mat.*—Solution of common salt (NaCl), solution of silver nitrate ($AgNO_3$) small iron tack, HCl, and solution of potassium ferro-cyanide.

Exp. 11.—Put some of the NaCl solution in a test-tube and add to it a few drops of $AgNO_3$. A white precipitate of silver chloride is formed. Preserve the contents of the tube.

Exp. 12.—Dissolve by heating the tack in 2 c.c. of HCl, dilute the solution with H_2O to three times its bulk, and add a few drops of HNO_3. Then add a little of the ferro-cyanide. A blue precipitate (Prussian blue) is formed.

FILTRATION.

Filtration, in chemistry, is the separation of a precipitate or other finely divided solid from a liquid with which it is mixed. The operation ordinarily consists in pouring the mixture on a properly folded piece of unsized paper placed in a funnel (p. 140), when the solid will remain on the paper and the liquid pass through. The liquid which has passed through is called the *filtrate.*

TO SHOW FILTRATION.—*App.*—Funnel containing a filter and supported in a filter stand (p. 140). *Mat.*—The mixture from exp. 11.

Exp. 13.—Pour the mixture on the filter. The solid and liquid will be completely separated.

DISTILLATION.

Distillation is the vaporization of a liquid and the condensation of the vapor. It affords a means of separating a liquid from the solid matter it may hold in solution, as H_2O from its foreign ingredients (Exp. 21), and also of separating two

liquids which do not vaporize at the same temperature, as H_2O and alcohol.

Destructive or *dry distillation* is distillation in which the condensed products are formed by the decomposition of substances (often in a dry state) heated in the retort.

Heating on Charcoal.

A small basin-shaped cavity is made in the coal by rotary motion with the spring end of a pair of pincettes or with a knife. The substance is put into the cavity and the flame inclined downward upon it.

Specific Gravity. (Sp. Gr.)

The **Specific Gravity** of a body is its weight compared with the weight of an equal volume of another body taken as a standard. The standard for solids and liquids is distilled H_2O at a temperature of 39.2° F. (4° C.); the standard for aeriform bodies is air or H.

The sp. gr. of a solid is found by weighing the body in air and in H_2O, and dividing the weight in air by the difference of these weights, which is the weight of a volume of H_2O equal to the volume of the solid.

To Find Sp. Gr.—*App.*—Balance, small beaker (or other vessel) containing some H_2O, small stool on which to support the beaker over the scale-pan, if the pan is not removed, and a fine thread. *Mat.*—Gold ring (or any small heavy body).

Exp. 14.—Weigh the body, then suspend it by means of the thread in the H_2O and weigh again. From these weights find the sp. gr. In making accurate determinations, the suspending thread should be counterpoised by a thread of equal weight.

The sp. gr. of a liquid is found either by direct weighing, or by the depth to which an instrument, called the *hydrometer*, will sink in it.

INORGANIC CHEMISTRY.

HYDROGEN (H). 1.

The standard of atomic weights and of quantivalence; a standard of specific gravity.

Properties.

H is a transparent, colorless, odorless gas. It is the lightest and most diffusible substance known, being about 14½ times lighter, and diffusing 4 times more rapidly than air. It burns with a slightly luminous and intensely hot flame, but does not support combustion. The product of the burning is H_2O.

Occurrence and Preparation.

H occurs free in nature in meteors, in the gaseous products of volcanoes, and in the atmospheres of the sun and stars. In combination it is very abundant and widely diffused, being a constituent of H_2O and of all organic substances.

H may be prepared from HCl or H_2SO_4 by means of zinc (Zn) or iron (Fe).

To Prepare H from HCl.—*App.*—Generator, delivery tube, pneumatic trough, and bottle gas-holder (p. 137). A generator is shown in Fig. 1. It consists of a wide-mouthed half-litre bottle with a closely fitting cork, through which is inserted a funnel tube reaching nearly to the bottom, and a short tube extending just through the cork. The delivery tube may be a glass tube (d) with the ends bent in opposite directions, or a rubber tube with a short bent glass tube at one end. The glass delivery tube is connected with the generator tube by a piece of rubber tubing. *Mat.*—20 g. sheet

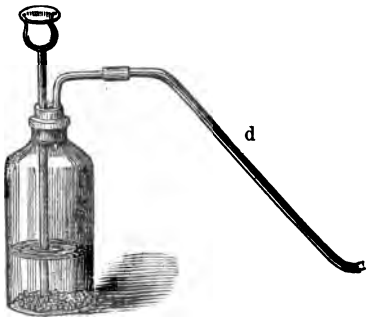

Fig. 1.—Gas Generator.

Zn cut into small pieces, or better, granulated Zn (prepared by pouring very hot melted Zn into cold H_2O) and HCl.

Exp. 15.—Arrange to collect the gas over H_2O (p. 136). Put the Zn in the generator and cover it with H_2O; connect the delivery tube with the generator and let the free end dip into the H_2O in the trough. Then put some HCl in the generator through the funnel tube. H is rapidly produced. Allow the bubbles that first pass off, which consist of air contained in the apparatus, to escape for a few seconds, then put the end of the delivery tube under the mouth of the bottle and collect the gas. Fill the bottle, adding more HCl if necessary, and preserve the gas by leaving the bottle inverted in the trough.

Reaction.—$Zn + 2\ HCl = 2\ H + ZnCl_2$ (zinc chloride).

Exp. 16.—Obtain $ZnCl_2$, which is in solution in the tube, by pouring the contents of the tube on a filter and evaporating the filtrate.

A large test-tube with a rubber cork containing a short glass tube, makes a convenient generator. If such generator be used, a smaller quantity of Zn should be used, more being added when necessary, and when the HCl is exhausted the $ZnCl_2$ should be poured off before more acid is added. Instead of preparing gas enough for all the experiments at the same time, it may be prepared as needed and collected in the receiver to be used in performing the experiment.

Illustrations of the Properties of H.

Lightness of H.—*App.*—Common clay pipe, sheet of foolscap paper, 2 ft. No. 16 wire, piece of strong thread, retort stand, pneumatic trough, and wide-mouthed l. bottle with cover. The mouth of the bottle should be ground and provided with a ground glass cover which may be a piece of ground window-glass (p. 145). A piece of wet paper may be used as a cover. *Mat.*—The bottle of H from Exp. 15, and soap-bubble liquid prepared by stirring for several minutes shavings of castile soap with warm H_2O, then pouring the mixture on a muslin filter, and adding to the filtrate about one-third of its volume of glycerine.

Exp. 17.—Cork the gas bottle, place it erect on the table, and connect it with the H_2O bottle as for blowing (p. 136). Connect the clay pipe with the air-tube and start the H_2O. Then, quickly grasping the air-tube between the thumb and a finger of one hand in order to regulate the flow of the gas, take the pipe in the other, and, using the soap-bubble liquid, inflate bubbles with H. The gas should not be allowed to pass until the liquid film is obtained on the pipe. The bubbles may be thrown off by a jerk of the pipe, or may be blown off.

Exp. 18.—Make the foolscap paper into a cylinder, paste the edges carefully together, and close one end of it by pressing the halves of the

rim together and uniting them with paste. Then with threads attach the cylinder *inverted* to one end of the wire and suspend the wire from a ring of the stand, so that it will be horizontal. Fill the l. bottle with H_2O and place it inverted on the shelf of the trough. Put the air-tube of the gas-holder into the bottle and transfer H as air is carried to a flame, filling the bottle. Cover the bottle, adjust it with its mouth directly under, and close to the mouth of the paper cylinder, and quickly remove the cover. The H rapidly expels air from the cylinder, and the wire beam turns, showing the lightness of the gas.

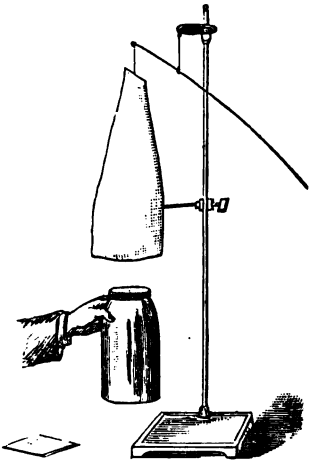

FIG. 2.—LIGHTNESS OF H.

DIFFUSIBILITY OF H.—*App.*—2 soda-water bottles with the mouths ground (p. 145), so that one will stand inverted upon the other. *Mat.*—H.

Exp. 19.—Grease the ground surfaces of the bottles, fill one of them with H and invert it upon the other (filled with air). Allow the bottles to stand thus connected for ten minutes, then bring a lighted match to the mouth of each bottle. Explosions follow indicating that the gases have mixed (Exp. 73). Although air is 14½ times as heavy as H, the latter passes down through the former.

THE H FLAME, SINGING FLAME, FORMATION OF H_2O BY THE BURNING OF H.—*App.*—Jet-tube consisting of a glass tube (p. 144) 8 or 10 in. long, with one end drawn out until the opening is very small, piece of fine iron wire, and 2 or 3 glass tubes about ¾ of an in. in diameter, and 1 to 2 ft. long; cylindrical lamp chimneys, or the necks of retorts, will answer the purpose. *Mat.*—H.

Exp. 20.—Connect the jet-tube with the delivery tube of the gas-holder connected with the H_2O bottle, and force gas through it. After waiting a few seconds for the air to be expelled (see caution below) light the H jet. *To test the temperature of the flame*, hold in it the iron wire, which readily melts. Hold the jet-tube upright in one hand and lower around it one of the large tubes. The flame may produce a musical tone. If it does not, the tone may be produced by raising or lowering the tube, varying the size of the flame, using another tube, increasing the pressure by raising the H_2O bottle higher, or by redraw-

ing the point of the jet-tube. Try to make the flame sing. The sound is due to slight explosions quickly following one another, caused by air drawn up the tube. *Notice the H_2O which has formed on the inner walls of the tube by the burning H.* It is due to the H combining with O of the air.

Caution.—Great care should be taken in making experiments which require H to be lighted, to have the gas unmixed with air, as H and air form an explosive mixture. If the gas cannot be used immediately after it is prepared, it should always be kept until ready for use in an inverted bottle with its mouth under H_2O.

H Does Not Support Combustion.—*App.*—Wide-mouthed l. bottle and pine splinter. *Mat.*—H.

Exp. 21.—Fill the bottle with H. Light the splinter, and, holding the bottle inverted at a convenient height, push the lighted splinter into it and slowly withdraw it. The light, which kindles the gas at the mouth, is extinguished, but the splinter is relighted again when its glowing end reaches the burning H. Push the splinter into the gas again and withdraw it.

Uses and Tests.

H is burned (supported by a jet of O) to produce heat for melting platinum and other substances difficult to fuse, and to produce the calcium light. It is known mainly by its lightness, by its flame, and by its property of burning but not supporting combustion.

Water (H_2O).

Properties and Occurrence.

H_2O, when pure, is a transparent, colorless, odorless, tasteless substance. It is a common solvent and the medium of many chemical changes. It is the most abundant of all substances, covering three-fourths of the earth, forming, as vapor, part of the atmosphere, and constituting the chief ingredient of organic beings. It is called the life-blood of nature.

Composition.

H_2O is composed of 1 part by volume of O to 2 of H, or 8 parts by weight of O to 1 of H. Its composition may be established both by analysis and synthesis.

H_2O may be analyzed in various ways, the most satisfactory of which is by means of a powerful voltaic current (Nat. Ph., p. 285). Its composition is shown by synthesis in Exp. 20, the product of the combustion (due to the union of O and H) being H_2O; also in Exp. 73, small drops of H_2O being produced on the sides of the bottle in which the gaseous mixture is exploded.

Impurities and Purification.

Natural waters are always impure. The impurities consist of various mineral and organic substances, either dissolved or held mechanically suspended, and sometimes of minute animals called *infusoria*. The purest natural water is rain or snow water.

H_2O is freed from its suspended impurities by filtration. For household purposes it is generally purified by passing it through filters composed of alternate layers of charcoal, sand, and gravel. For important chemical operations it is subjected to a process called *distillation* (p. 21), and this process is sometimes repeated to render the water as nearly pure as possible.

Distillation of H_2O.—App.—Distillling app., flask for receiver, retort stand, and lamp. The distilling app. may consist of a retort in which to heat the liquid and a glass tube to serve as a condenser. The tube should be about 18 in. long and large enough to admit the end of the tube of the retort with a band of rubber or wet cloth around it. The condenser tube may be dispensed with and the tube of the retort put into the receiver, which should then be supported in H_2O and covered with a wet cloth. *Mat.*—H_2O.

Fig. 3.—Distilling Apparatus.

Exp. 21.—Support the retort on a ring of the stand, placing it on wire gauze if an alcohol or gas lamp is to be used, and support the receiver with the free end of the condenser in it. Then put H_2O in the retort and heat, continuing the operation until nearly all the H_2O has passed over.

Prove the purity of the distilled H_2O as follows: Evaporate slowly to dryness a few drops of it on a piece of clean glass. No residue will remain. Evaporate a like quantity of H_2O from the retort in the same manner. A distinct spot of earthy matter will remain on the glass.

Hydrogen Dioxide. (H_2O_2)

H_2O_2 is a colorless, oily liquid, which at 100° C. separates into O and H_2O with great energy. It is an active bleaching agent, possessing the property of bleaching without injuring the fabric. It is prepared by the action of HCl or H_2SO_4 on barium dioxide.

PRACTICAL QUESTIONS.

1. Name some compounds that contain H. Some that do not contain H.

2. Of what classes of compounds is H a common element? What is the weight of a litre of H? A gallon?

3. How much H can be prepared by using 10 g. of Zn? By using 10 g. of HCl?

4. How much Zn and HCl would be required to produce 10 g. of H? To produce 1 gallon?

5. How can it be shown that H_2O is a product of the combustion of H?

6. How much H must be burned to yield a gallon of H_2O?

7. How much H_2O will a pound of H yield in burning? A gallon of H?

8. The reaction in the preparation of H from H_2SO_4 is expressed thus:

$$Zn + H_2SO_4 = 2\,H + ZnSO_4 \text{ (zinc sulphate)}.$$

By which of the two methods is the greatest weight of H produced with the same weight of acids?

9. Can you name any substances that do not contain H_2O?

10. How would you determine the amount of moisture in a substance?

11. What weight of H in a gallon of H_2O? What volume of H? What is the difference between spring H_2O and sea H_2O?

12. Why is rain H_2O "soft" and spring H_2O often "hard?"

13. What process in nature is similar to the distillation of H_2O in the laboratory?

14. What weight of H_2O in 10 pounds of blue vitriol (67)?

15. What is the difference in the percentage composition of H_2O and H_2O_2?

SODIUM GROUP.

SODIUM, POTASSIUM, LITHIUM, RUBIDIUM, CÆSIUM, SILVER.

The elements of this group are *monads.* The compounds of each of them give peculiar colors to the flame of a lamp. Most of these compounds are soluble in H_2O, and their oxides and hydrates, the *caustic alkalies,* are very corrosive.

SODIUM (Na) 23.

PROPERTIES.

Na is a soft white metal with the lustre of silver. It quickly oxidizes in moist air, and hence is preserved in a liquid which contains no O, as naphtha or petroleum. Na decomposes H_2O at the lowest temperatures, liberating its H and combining with its O.

DECOMPOSING OF H_2O BY Na.—*Mat.*—H_2O in a beaker (or wide-mouthed bottle) with cover, hot H_2O, 2 pieces of Na as large as grains of wheat and red litmus paper.

Exp. 22.—Put a piece of the Na on the H_2O, and cover the vessel. The action is very energetic. The freed H passes into the air, and the new compound of O and Na (sodium hydrate) dissolves in the H_2O. Test the liquid with the litmus paper; it will color the paper blue. Evaporate it to dryness to obtain the hydrate.

FIG. 4.—Na ON HOT WATER.

Exp. 23.—Put the other piece of Na on the hot H_2O. The freed H burns, the flame being colored yellow by vapor of the metal.

Occurrence and Preparation.

Na does not occur free in nature. Its chief source is common salt, which is also the source of most of the Na compounds. It is commonly prepared by distilling a mixture of sodium carbonate and charcoal.

Sodium Hydrate (NaHO.)

NaHO (caustic soda) is a white amorphous solid, with a strong affinity for H_2O, in which it readily dissolves, a very caustic and alkaline solution being formed. In air it deliquesces and absorbs CO_2, changing to a carbonate. It combines with fats and oils to form hard soaps. NaHO is prepared by mixing milk of lime (whitewash) with a solution of sodium carbonate, NaHO and calcium carbonate being formed. "Concentrated lye" is an impure NaHO.

Sodium Chloride (NaCl.)

Properties.

NaCl (common salt) is a white crystalline salt, crystallizing in cubes. Its slightly bitter taste is due to the presence of a little magnesium chloride. It dissolves in about three times its weight of H_2O, and is nearly as soluble in cold as in hot H_2O.

To Prepare Crystals of NaCl.—*App.*—2 small beakers and app. for filtering. *Mat.*—NaCl and H_2O.

Exp. 24.—Make a strong solution of NaCl in one beaker, filter it into the other, and place the filtrate where it will be undisturbed for several hours. Little cubes of the substance separate; examine them with a lens.

Fig. 5.

Occurrence and Preparation.

NaCl occurs in solution in the ocean and in saline springs, and in a mineral form as rock salt. The water of the ocean contains about 4 oz. of NaCl to the gallon. Rock salt is

abundant. Near Cracow, Poland, there is a vein 500 miles long, 20 miles wide, and 1200 feet thick. It is also extensively mined at Stassfurt in Prussia, Salzburg in Austria, Petit Anse in Louisiana, and various other places.

NaCl is generally obtained by evaporation from its solution, which, in climates sufficiently warm, is effected by the heat of the sun. When natural deposits of salt are mixed with large quantities of earthy impurities, the salt is obtained by letting H_2O into the bed, allowing it to remain until saturated, and then evaporating the solution. When the saturated solution is evaporated rapidly, the product is fine salt; evaporated slowly, it is coarse salt. The most extensive salt works in the United States are in Onondaga County, New York.

Uses.

NaCl is an essential constituent of our food.* It is used in large quantities for preserving meat and fish, in glazing earthenware, and in preparing other Na compounds. It is used in the laboratory in the preparation of Cl and HCl.

Sodium Sulphate (Na_2SO_4).

Na_2SO_4 is a white salt easily soluble in H_2O. Its solution produces crystals called *Glauber's salt* ($Na_2SO_4 + 10\ H_2O$), which effloresce in dry air, forming Na_2SO_4. It is an intermediate product in the preparation of sodium carbonate from NaCl.

Sodium Carbonate (Na_2CO_3).

Na_2CO_3 is a white alkaline salt, soluble in H_2O. Its solution produces crystals, called *sal soda* ($Na_2CO_3 + 10\ H_2O$, washing soda), which effloresce in dry air, forming Na_2CO_3.

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*Common salt is universally prized as an article of food. It is said that in some parts of Africa the most valuable possessions, even wives and children, are bartered for salt, and that its use is a sign of riches. Depriving criminals of the use of salt was a mode of punishment in ancient times. It is estimated that each person in the United States consumes annually from 50 to 60 lbs. of salt.

Na_2CO_3 is prepared from NaCl by Leblanc's process,* which may be briefly stated as follows:

First Stage.—A mixture of NaCl and H_2SO_4 is heated, Na_2SO_4 and HCl fumes being produced. The latter are conducted over wet coke to form common HCl.

Second Stage.—The Na_2SO_4 is then heated in a reverberatory

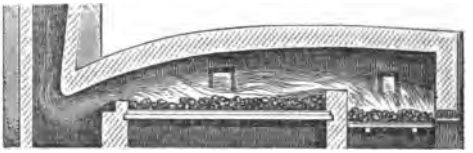

FIG. 6.—REVERBERATORY FURNACE.

furnace with chalk or limestone and fine coal. "Black ash," consisting mainly of Na_2CO_3 and CaS, is produced. The "black ash" is washed with warm H_2O, the solution evaporated to dryness, and the residue roasted with sawdust. The product thus obtained, containing about 80 per cent. of Na_2CO_3, is the "soda ash" of commerce.

Hydrogen Sodium Carbonate ($HNaCO_3$, bi-carbonate of soda) is a white powder prepared by exposing Na_2CO_3 to CO_2. It is used in raising bread, etc., and in effervescing powders, and is known by cooks and grocers as "soda."

Na Nitrate (*$NaNO_3$*), *Na Biborate* (*$Na_2B_2O_7$*).

$NaNO_3$ (soda-saltpetre) is a white crystalline salt, found in the desert districts of Peru and Nevada. It is used in preparing HNO_3 and as a fertilizer.

$Na_2B_4O_7$ (borax) is a white crystalline salt soluble in H_2O. It occurs in many mineral springs, in certain lakes, as Borax

* Sodium carbonate was formerly produced only from the ashes of sea weeds growing along the coasts of France, Spain, and Scotland, and it became so high in price during the French Revolution that Napoleon offered a premium for the discovery of a process by which it could be more cheaply produced. To this circumstance we are indebted for Leblanc's process, which came into use about the year 1820. This discovery, by cheapening the production of many much-used products, is justly regarded as a very important event in the history of chemistry.

Lake of California, and in ancient lake beds, as the "marshes" of Nevada. It is manufactured in large quantities from the crude boric acid of Tuscany, and from calcium borate of Nevada.

POTASSIUM (K) 39.1.

Properties.

K closely resembles Na in appearance and properties; it has, however, a bluish color, and decomposes H_2O with so much energy that the heat produced is sufficient to kindle the H.

Fig. 7.—K on Water.

Decomposing of H_2O by K.—*Mat.* —H_2O in a beaker (or wide-mouthed bottle) with cover and piece of K as large as a grain of wheat.

Exp. 25.—Put the K on the H_2O and cover the vessel. The H burns with a purplish-red flame, the color being due to a small quantity of the vaporized metal.

Occurrence and Preparation.

K does not occur free in nature, but its compounds are widely distributed, being found in all fertile soils. It is prepared by heating intensely a mixture of potassium carbonate and charcoal.

K Hydrate and Other K Compounds.

Potassium Hydrate (KHO, caustic potash) closely resembles NaHO, but it is more strongly alkaline. Its preparation is similar to that of NaHO. It combines with fats and oils to form soft soaps.

Potassium Chloride (KCl) closely resembles NaCl. It is found in sea water and in the saline deposits at Stassfurt.

Potassium Bromide (KBr) **and Iodide** (KI) resemble the chloride. They are used in medicine and photography.

Potassium Cyanide (KCN) is a white, fusible, poisonous solid used in electro-plating. It poisons when in contact with a cut or scratch in the skin.

Potassium Carbonate (K_2CO_3).

K_2CO_3 is a white crystalline salt, deliquescent and soluble in H_2O. It is prepared from the sulphate by Leblanc's process, and also from the ashes of plants. The refined product is called *pearlash*. K_2CO_3 is used in the manufacture of soap and glass, and in preparing other K compounds.

To Obtain K_2CO_3 from Wood Ashes.—*App.*—App. for filtering and an evaporator. *Mat.*—Wood ashes and hot H_2O.

Exp. 26.—Fill the filter with ashes and pour hot H_2O on them, collecting the liquid in the evaporator. Pass the liquid through the ashes several times and evaporate it to dryness. The residue is crude K_2CO_3.

Hydrogen Potassium Carbonate ($HKCO_3$, bi-carbonate of potash, saleratus) is a white crystalline substance prepared by passing CO_2 through a solution of K_2CO_3.

Potassium Nitrate (KNO_3).

KNO_3 (nitre, saltpetre) is a white crystalline salt, very soluble in hot H_2O, and an energetic oxidizing agent. It is a natural product, its chief source being the soil of certain districts of India, Persia, and other tropical regions. It is used chiefly as an ingredient of gunpowder, which is a mixture of 6 parts KNO_3, 1 part S and 1 part charcoal.

KNO_3 as an Oxidizing Agent.—*App.*—Piece of porcelain (or earthenware), lamp, and iron wire 6 in. long. *Mat.*—2 or 3 g. KNO_3 and ½ g. finely powdered charcoal.

Exp. 27.—Mix the KNO_3 and C together, put the mixture on the porcelain, and ignite it with the wire heated. The salt decomposes with vivid combustion, its O uniting with C to form CO_2.

Potassium Chlorate ($KClO_3$).

$KClO_3$ is a white crystalline salt, soluble in H_2O, and an energetic oxidizing agent. It is prepared by the action of Cl on milk of lime, followed by the conversion of the calcium

chlorate thus formed into $KClO_3$ by means of potassium chloride. It is much used in calico printing, medicine, pyrotechny, and in making some kinds of friction matches.

$KClO_3$ AS AN OXIDIZING AGENT.—*App.*—Mortar, anvil (or flat-iron), hammer, piece of tin 4 or 5 in. square, and half a sheet of foolscap paper. *Mat.*—Piece of phosphorus (P) as large as a pin's head, 2½ g. $KClO_3$, 2 g. white sugar, and strong H_2SO_4.

Exp. 28.—Powder the $KClO_3$ finely (see caution below), put the P on a piece of paper, cover it with $KClO_3$ and wrap the two substances tightly in the paper; then place the package on the anvil and strike it with the hammer. The stroke is followed by a sharp explosion.

Caution.—In pulverizing $KClO_3$, the mortar and pestle should be clean, and the crystals should not be struck nor strong pressure used.

Exp. 29.—Powder the sugar and mix it thoroughly with the remaining $KClO_3$; pour the mixture in a paper tube; then put the tube on the tin, and let fall on the mixture, at one end of the tube, a drop of H_2SO_4. The mass burns with great energy.

TESTS FOR Na AND K.

The flame tests are simplest. Na salts color the upper part of an alcohol or gas flame yellow, and K salts, purple or violet. Flame tests are made by placing a drop of the solution of the substance by means of a platinum wire in the flame; one end of the wire (which should be about as thick as coarse sewing thread) is bent into a small loop, and this is dipped into the solution, and then put into the flame. (p. 146).

Exp. 30.—Make flame tests for Na and K, using solutions of NaCl and KNO_3. Insert the wire at the point of the blue cone.

Exp. 31.—Prepare Na_2SO_4 and K_2SO_4 by adding (not in excess) dilute H_2SO_4 to solutions of Na_2CO_3 and K_2CO_3. Obtain crystals of the substances. *Exp.* 32.—Prepare crystals from strong H_2O solutions of Na_2CO_3 and K_2CO_3. Expose for several hours a crystal of each substance to dry air, and one of each to moist air, and notice how the crystals are changed by this treatment.

The other members of the Na group are rare metals. Lithium is the lightest metal known, having a sp. gr. of only 0.59. Its volatile compounds color the flame carmine red. These metals are always found with Na and K, but in very small quantities.

SILVER (Ag) 108.

Properties.

Ag is a white, very malleable, ductile metal, and the best conductor of heat and electricity. Sp. gr. 10.5. It does not change in air, but blackens in air containing hydrogen sulphide, which is always present in rooms heated with coal fires. The black coating is silver sulphide. Ag dissolves readily in HNO_3.

Occurrence and Preparation.

Ag is widely distributed and somewhat abundant in nature. It frequently occurs in the metallic state, but generally in combination, its most abundant ore being the sulphide mixed with lead sulphide. A large deposit of the carbonate occurs at Leadville, Colorado.

Among the richest of the long-known silver mines are those of Mexico and Peru. The famous Comstock lode, in Nevada, has proved the richest mine in the world, having yielded $70,000,000 worth of Ag in seven years.

Ag is separated from its ores in several ways. By the *amalgamation* process a silver amalgam is produced by the addition of mercury to the ore, and the mercury is removed from the compound by distillation. By the *cupel* process an alloy of Ag and lead is formed, and the lead removed by oxidation.

The various uses of Ag are well known. It is generally alloyed with a small amount of copper to increase its hardness. Our silver coins contain 10 per cent. of copper.*

Ag Chloride ($AgCl$), Ag Nitrate ($AgNO_3$).

AgCl is a white crystalline salt which may be prepared by adding HCl or a solution of NaCl to a solution of $AgNO_3$. It is frequently found as a compact mineral which, from its horny texture, is called *horn* silver.

* The date of the first use of silver is unknown. According to the Old Testament it formed part of the riches of Abraham, and was abundant in Solomon's reign. Pliny (born A. D. 23) speaks of a mine which supplied him 300 lbs. of the metal a day. Silver was called by the alchemists *Luna* or *Diana*. Silver was first known as "white gold."

$AgNO_3$ is a white crystalline salt, soluble in H_2O; when melted and cast into sticks it is called *lunar caustic.* When in contact with organic matter, $AgNO_3$ is decomposed by light, the reaction producing a black stain which cannot be removed by washing. Hence its use in the preparation of hair dyes and indelible ink. It is used in surgery and photography. It is prepared from a solution of Ag in dilute HNO_3. The nitrate stains and indelible ink can be removed by applying a solution of potassium cyanide. (p. 34).

Exp. 33.—Prepare AgCl from a solution of a piece of Ag coin in HNO_3. It is formed as a white cheesy precipitate. The copper remains in solution. Expose the AgCl to sunlight and it will become brown.

TESTS.

Most Ag compounds yield Ag when heated in a blowpipe flame, and Ag compounds in solution give, with any soluble chloride, precipitates of AgCl which darken in sunlight (Exp. 33).

Exp. 34.—Obtain a globule of Ag by heating some AgCl with some dry potassium carbonate (K_2CO_3) on charcoal. The Cl is removed by the K of the K_2CO_3.

PRACTICAL QUESTIONS.

1. What weight of Na in 5 oz. of NaCl? Of K in 5 oz. KNO_3?
2. What is the composition of lye obtained from wood ashes?
3. What Na compound contains the largest amount of Na? What K compound the largest amount of K?
4. If intrinsic values only are considered, what relation should the value of Na_2CO_3 bear to $Na_2CO_3 + 10\ H_2O$?
5. Why is $HNaCO_3$ used in making bread, cakes, etc.?
6. For hurried baking which is better, "soda" or "saleratus?"
7. How many litres of CO_2 can be obtained from 10 g. of Na_2CO_3? 10 g. of $HNaCO_3$? 10 g. of $Na_2CO_3 + 10\ H_2O$?
8. What Ag compound contains the largest amount of Ag?
9. How much AgCl could be made from a half dollar? (Find the weight of the coin.)
10. How much NaCl would be required to precipitate 1 g. of Ag? How much HCl?

CHLORINE GROUP.

CHLORINE, BROMINE, IODINE, FLUORINE.

The elements of this group are *monads*. They all form acids with H, and salts, of which common salt is the type, with certain metals. Their chemical energies are inversely as their atomic weights.

CHLORINE (Cl) 35.5.

Properties.

Cl is a yellowish-green suffocating gas, nearly 2½ times as heavy as air, and very soluble in H_2O. It combines with certain substances, as H, oil of turpentine, and antimony, with great energy, and is an active bleaching agent.

Caution.—Experiments with Cl should be made in a draught of air. The strong gas should not be inhaled.

Occurrence and Preparation.

Cl does not occur free in nature, but is abundant in combination. It occurs most abundantly in common salt (NaCl) forming about three-fifths by weight of this compound.

Cl may be prepared from HCl by means of manganese dioxide (MnO_2); from NaCl by means of MnO_2 and H_2SO_4; or from bleaching powder ($CaOCl_2$) by means of H_2SO_4.

Fig. 8.—Preparation of Cl.

To Prepare Cl from HCl.—*App.*—Half l. flask with cork to which a delivery tube is attached, retort stand, 3 wide-mouthed half l. bottles with covers, and lamp. The tops of the bottles should be greased to enable the covers to fit more closely. *Mat.*—5 g. MnO_2, and HCl.

Exp. 35.—Support the flask on a ri g of the stand, place the bottle

erect on the table and put the free end of the delivery tube into it, extending it to the bottom. Put the MnO_2 in the flask and add to it about 10 c.c. of HCl, then cork the flask and heat gently. As the Cl collects, the air in the bottle is slowly expelled. When the bottle is full, which is indicated by the yellowish-green color of the entire contents, carefully cover it. Fill also the other bottles and preserve the Cl.

Cl is not collected over H_2O because it is so readily absorbed by H_2O. It may be collected over *hot* H_2O or brine.

Reaction.—$MnO_2 + 4\ HCl = 2\ Cl + 2\ H_2O + MnCl_2$ (manganese chloride).

Exp. 36.—Obtain the $MnCl_2$ by pouring the contents of the generator on a filter and evaporating the filtrate.

To PREPARE Cl FROM NaCl AND FROM $CaOCl_2$.—*App.*—2 test-tubes and lamp. *Mat.*—2 g. NaCl, 2 g. MnO_2, 2 g. $CaOCl_2$, H_2O and H_2SO_4.

Exp. 37.—Put the NaCl and MnO_2 in one tube and the $CaOCl_2$ in the other. Put in each tube some H_2O and 2 or 3 c.c. of H_2SO_4, and heat. Cl, known by its color and smell, is given off from each tube.

ILLUSTRATIONS OF PROPERTIES.

COMBINING OF Cl AND H.—The *App.* and *Mat.* used to generate Cl, and H, soda-water bottle, small pneumatic trough containing brine and narrow strip of blue litmus paper.

Exp. 38.—Half fill the soda-water bottle, screened from strong light by a wrapping of cloth or paper, with Cl, and the remainder with H. Then remove the bottle from the trough and quickly bring a lighted match to its mouth. The gases combine with a sharp explosion, forming HCl. Prove the presence of HCl by wetting the litmus paper and suspending it in the bottle just after the explosion has occurred.

FIG. 9.—COMBINING OF H AND Cl.

DISSOLVING OF Cl IN H_2O.—*App.*—The generator used in Exp. 15 and a qr. l. bottle. *Mat.*—Bottle of Cl, 2 g. MnO_2, HCl, and H_2O.

Exp. 39.—Put some H_2O in the bottle of Cl, close the bottle with the hand, and shake it. The H_2O absorbs the gas, the vacuum produced causing the hand to be pressed tightly against the mouth of the bottle.

Exp. 40.—Put some H_2O in the qr. l. bottle and pass a current of Cl, prepared as in Exp. 35, through it by extending the delivery tube to the

bottom of the bottle. The H_2O absorbs the gas, forming *chlorine water*. When the H_2O has become saturated (smells strongly of Cl), preserve it by carefully corking the bottle.

FIG. 10.—PREPARING CHLORINE WATER.

BURNING OF OIL OF TURPENTINE ($C_{10}H_{16}$) IN Cl.—*App.*—Test-tube, lamp, and strip of filter paper about an in. wide. *Mat.*—Bottle of Cl and $C_{10}H_{16}$.

Exp. 41.—Put 5 or 6 c.c. of $C_{10}H_{16}$ in the tube and heat, then dip the paper, folded two or three times lengthwise, into it and thrust the paper into the Cl. A dense smoke is produced and the paper may ignite. The Cl combines with the H of the oil, liberating the C (smoke).

FIG. 11.—$C_{10}H_{16}$ BURNING IN Cl.

BURNING OF ANTIMONY (Sb) IN Cl.—*App.*—Lamp, mortar, and piece of tin. *Mat.*—Bottle of Cl and 1 g. Sb.

Exp. 42.—Powder finely the Sb, dry it on the tin over the lamp, and sprinkle it into the Cl. The metal ignites and falls glowing to the bottom of the bottle, a portion of the product formed appearing as a heavy white smoke.

Cl AS A BLEACHING AGENT.—*App.*—3 small beakers, 3 test-tubes, retort stand, and kerosene lamp. *Mat.*—5 g. MnO_2, 5 g. $CaOCl_2$, Cl water, HCl, H_2SO_4, chocolate-colored calico, ink-stained muslin, piece of paper on which there is printing and writing with ink and with a lead pencil, and small quantities of solutions of litmus, of indigo, and of an aniline color.

Exp. 43.—Put some MnO_2 and HCl in each beaker. Cover one of the beakers with a piece of the calico, another with a piece of the stained muslin, and the third with the paper; wet the covers with H_2O, and support the beakers in turn for several minutes over the lamp with a low flame. The calico will be bleached and the spots and ink writing removed; the printing and pencil writing, however, will remain.

Exp. 44.—Nearly fill the test-tubes with Cl water and put in each a few drops of one of the colored solutions. The colors disappear. Pour some Cl water on ink writing and notice the effect.

Exp. 45.—Put the $CaOCl_2$ and H_2O in a beaker, and some dilute H_2SO_4 in another beaker. Immerse a piece of the calico in one liquid, then in the other several times; wash the calico. Its color is destroyed.

In bleaching on a large scale, the article is first cleansed of grease by boiling it in an alkali, it is then saturated with dilute H_2SO_4, and finally passed through a solution of $CaOCl_2$. The H_2SO_4 liberates Cl from the powder.

The action of Cl in bleaching is to take H from H_2O, the O of which combines with the color, forming a colorless compound. Hence Cl must contain H_2O in order to bleach.

To Show that Dry Cl Will Not Bleach.—*App.*—Test-tube and roll of paper made out of a strip of paper ½ in. wide that will fit closely in the tube. *Mat.*—2 g. MnO_2, HCl, calcium chloride ($CaCl_2$) or bleaching powder, and H_2O.

Exp. 46.—Put the MnO_2 and some HCl in the test-tube, push in the roll of paper 2 in. and cover it with a layer of $CaCl_2$ 1 in. thick. Then cover the tube with a piece of *dry* calico and heat gently. The Cl is dried by the $CaCl_2$ and has no action on the calico. Put a few drops of H_2O on the calico, and it will bleach as previously shown.

Uses and Tests.

The chief use of Cl is for bleaching. It is also used as a disinfectant, and for this purpose is conveniently produced by exposing bleaching powder mixed with H_2O to air, the CO_2 of the air decomposing the substance.

Cl is known by its odor and color. It may be detected in many compounds by adding to a solution of the compound a solution of silver nitrate. A white precipitate of silver chloride, which is insoluble in HNO_3, is produced.

Exp. 47.—Prove the presence of Cl in common salt.

Hydrochloric Acid (HCl).

HCl (hydrogen chloride, muriatic acid), the only known compound of H and Cl, is a colorless, pungent acid gas. It is very soluble in H_2O, one volume of H_2O, at 0°C. dissolving more than 500 volumes of the gas. The solution of HCl in H_2O is common muriatic acid. HCl dissolves most of the metals and their oxides. Compounds formed by the action of HCl on metals, etc., are called *chlorides*.

HCl occurs free in nature in the gaseous products of active volcanoes, and in the waters of some volcanic districts. It

may be prepared from H_2SO_4 and common salt (NaCl). Most of the HCl of commerce is a secondary product of the alkali manufacture.

To PREPARE HCl.—*App.*—Same as that used in preparing Cl; only one qr. l. bottle is needed. *Mat.*—5 g. NaCl, 5 c.c. H_2SO_4 and bit of blue litmus paper.

Exp. 48.—Arrange to collect the gas as Cl was collected. Stick with H_2O the litmus paper on the rim of the bottle, put the NaCl and H_2SO_4 in the flask, and heat. Fill the bottle; it is full when the litmus paper turns red. Cover the bottle and preserve the gas.

Reaction.—$NaCl + H_2SO_4 = HCl + HNaSO_4$ (hydrogen sodium sulphate).

Exp. 49.—Obtain the $HNaSO_4$ by pouring the contents of the flask on a filter and evaporating the filtrate.

DISSOLVING OF HCl IN H_2O.—*App.* and *Mat.*—The bottle of HCl gas from Exp. 48, a shallow dish containing H_2O colored slightly blue with litmus, the app. and half the NaCl and H_2SO_4 used in Exp. 48 and qr. l. bottle nearly full of H_2O.

Exp. 50.—Invert the bottle of gas in the blued H_2O. The H_2O rises in the vessel and turns red by the action of the acid.

Exp. 51.—Pass a current of HCl gas, prepared as in Exp. 48, through the H_2O in the bottle as shown in Fig. 10. The solution of the gas in the H_2O thus made is ordinary HCl. In preparing the acid in large quantities, iron cylinders are used as generators, and the gas is collected in a series of earthenware bottles.

HCl AS A SOLVENT.—*App.*—4 small test-tubes and lamp. *Mat.*—HCl and about ½ g. each of zinc, iron, iron rust, and black oxide of copper.

Exp. 52.—Put the metals and oxides in the tubes, add about 1 c.c. of HCl to each, and heat. They readily dissolve, their chlorides being formed. The chlorides may be obtained by evaporation.

USES AND TESTS.

HCl is much used in the chemical laboratory. It is used also in preparing bleaching powder and gelatine, as a solvent of metals, and for various other purposes.

HCl produces with ammonia dense white fumes $(NH_4)Cl$ (Exp. 122), and with a solution of silver nitrate ($AgNO_3$) a milky precipitate which is insoluble in $(NH_4)HO$, but soluble in HNO_3.

Exp. 53.—Make these tests, using for the latter very dilute acid and only a few drops of the $AgNO_3$ solution.

Aqua Regia.

Aqua Regia is a mixture of 3 volumes of strong HNO_3 with 5 volumes of strong HCl. It is used for dissolving gold and other metals not soluble in separate acids.

AQUA REGIA AS A SOLVENT.—*App.*—2 small test-tubes. *Mat.*—2 small pieces of gold leaf, HNO_3 and HCl.

Exp. 54.—Put 1 or 2 c.c. of HNO_3 in one tube and 2 or 3 c.c. of HCl. in the other, and put a piece of gold leaf in each tube (the leaf may be transferred to the tubes on the moistened end of a glass rod or lead pencil). Neither acid dissolves it. Mix the contents of the tubes in either tube and the gold rapidly dissolves, forming gold chloride.

In this action the acids decompose each other, liberating Cl, which acts (in the nascent state) on the gold.

FLUORINE (F) 19.

F is a gas, but it cannot be readily obtained in a free state; for when it is freed from a compound it immediately forms another with any substance with which it comes in contact. It is the only element that does not combine with O. It forms with H hydrofluoric acid (HF) which has a strong affinity for silicon, and may therefore be used for etching glass.

F occurs in the minerals, fluor spar (calcium fluoride, CaF_2), found in many localities, and cryolite (sodium and aluminum fluoride), found in extensive beds in Greenland.

TO ETCH WITH HF.—*App.*—Leaden dish, retort stand, and lamp. The dish may be made by sawing a ring $\frac{3}{4}$ of an in. wide from a piece of lead pipe, and soldering a piece of sheet lead to one of its ends for a bottom. Vessels of other material may be used, but they may be attacked either by the HF or the H_2SO_4. *Mat.*—2 g. CaF_2, and H_2SO_4, square of glass large enough to cover the cup, and lump of beeswax.

Exp. 55.—Coat the glass with the wax by heating the wax and daubing it on the glass, then heating the glass and allowing it to cool. If the coat is uneven, heat again. Now write on the glass through the wax with a pin or other pointed instrument.

Powder the CaF_2, put it into the dish and make it into a thin paste with H_2SO_4; then cover the dish with the coated glass, waxed surface

down, and support it over a very low flame. The wax must not melt: this may be prevented by covering the glass with a wet cloth. In half an hour remove the coating, scraping off most of it, then rubbing the plate with a cloth saturated with alcohol, and the writing will be etched on the glass.

FIG. 12.—ETCHING WITH F.

Etchings may be conveniently made on the convex surfaces of a watch glass or bulged lamp chimney, since H_2O may be put in the concavity, to prevent the wax from melting.

BROMINE (Br) 80.

Br is a brownish-red, volatile liquid, with a suffocating and offensive odor. It acts chemically much like Cl, but has less energy. Br does not occur free in nature, and its principal compound is magnesium bromide, found in sea water and in the waters of many saline springs. It is prepared very extensively from mother liquors obtained from Stassfurt in working the salts of potassium and magnesium. Some of the bromides are used extensively in photography and medicine.

TO PREPARE BR FROM POTASSIUM BROMIDE (KBr).—*App.*—3 test-tubes and lamp. *Mat.*—½ g. KBr, and H_2O, MnO_2, HCl, Cl water (Exp. 40), and ether.

Exp. 56.—Dissolve the KBr in 5 c.c. of H_2O. Put a little MnO_2 in a clean dry test-tube, add to it a few drops of HCl, then some of the KBr solution, and heat gently. The dark red vapor of Br will soon appear. The Br is expelled from the KBr by the Cl.

Exp. 57.—To the remainder of the KBr solution, add some Cl water, then some ether, and shake the mixture. A reddish layer of Br dissolved in ether will form at the top of the liquid.

IODINE (I) 127.

PROPERTIES.

I is a blue-black, crystalline solid with a metallic lustre. When gently heated, it yields a beautiful purple vapor, nearly 9 times as heavy as air, which crystallizes on cooling. It is only slightly soluble in H_2O, but dissolves readily in alcohol and ether. It acts chemically somewhat like Cl and Br, with less energy than Br.

VAPOR OF I.—*App.*—Long dry test-tube and lamp. *Mat.*—A few crystals of I.

Exp. 58.—Put the I in the tube and heat, holding the tube so that the vapor can be seen to best advantage. The I will crystallize on a cold part of the tube. Heat again and reconvert it into vapor.

DISSOLVING OF I IN ALCOHOL.—*App.*—Test-tube. *Mat.*—A few crystals of I and alcohol.

Exp. 59.—Shake the I in the test-tube with some alcohol. It dissolves, *tincture of I* being formed.

OCCURRENCE AND PREPARATION.

I does not occur free in nature. It is found in small quantities, combined with potassium and sodium, in sea water and in the waters of many saline and mineral springs.

TO PREPARE I FROM POTASSIUM IODIDE (KI).—*App.*—2 test-tubes and lamp. *Mat.*—0.3 g. KI and H_2O, MnO_2 and HCl.

Exp. 60.—Dissolve the KI in 1 c.c. of H_2O. Put a little MnO_2 in a clean dry test-tube, add to it a few drops of HCl, then some of the KI solution and heat gently. The violet vapor of I will soon appear.

USES AND TESTS.

I compounds are used in photography, in the chemical laboratory, and in medicine. I is known by its vapor. A delicate test is the blue color it forms with starch.

STARCH TEST FOR I.—*App.*—Small test-tube, lamp, and large, wide-mouthed bottle. *Mat.*—Tincture of I, a few crystals of I, starch paste (the kind used for laundry purposes), and strip of filter paper.

Exp. 61.—Mix a little starch paste with some H_2O in the test-tube, and add a few drops of tincture of I. The liquid becomes deep blue. Heat the liquid, and its color disappears; the color will reappear again when the liquid cools.

Exp. 62.—Put the I in the bottle; coat the strip of paper with starch paste and suspend it in the bottle. The paper is slowly colored blue by I vapor.

OXYGEN GROUP.

OXYGEN, SULPHUR, SELENIUM, TELLURIUM.

The elements of this group are *dyads*. They are especially characterized by their wide range of affinities.

OXYGEN (O) 16.

Properties.

O is a transparent, colorless, odorless gas about 1.1 times as heavy as air. It has great chemical activity, and combines with all the elements except fluorine, the combination producing *oxides*.

Occurrence and Preparation.

O occurs free in air (the gases of the air are *mixed*, not chemically combined); in combination it is very abundant. It is the most abundant and most widely diffused of all the elements, forming more than three-fourths of animals and plants, and one-half of the solid part of the earth's crust.

O is generally prepared from potassium chlorate ($KClO_3$) and manganese dioxide (MnO_2).

To Prepare O.—*App.*—Large test-tube with rubber cork containing a short glass tube, the delivery tube used in preparing H, wide-mouthed half l. bottle (for receiver) with cover, retort stand, lamp, mortar, crucible, and pneumatic trough. *Mat.*—5 g. $KClO_3$ and 3 g. MnO_2.

Exp. 63.—Arrange to collect the gas over H_2O (as in collecting H). Pulverize the $KClO_3$ (see Caution, p. 35) and mix it thoroughly with the MnO_2; dry the mixture by heating it gently in the crucible and put it into the test-tube, inclining the tube and distributing the mixture nearly to its mouth. Cork the tube, attach the delivery tube, and allow the free end of this to dip into the water, then heat. The tube, while being heated, may be held in the hand, or supported as shown in Fig. 13. After the bubbles (air) have escaped for a few seconds, collect the gas. Continue heating in the same place until all the O is expelled from the mixture directly over the flame, indicated by a stopping of the flow of bubbles. Fill the bottle with O. Preserve the gas for Exp. 64, and put the tube in the rack to preserve the unused material. When more O is needed the tube is heated again.

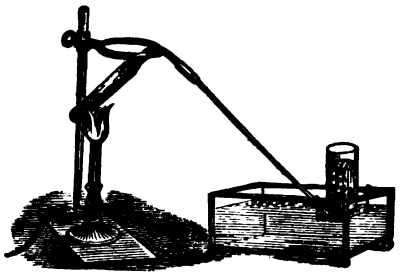

Fig. 13.—Preparation of O.

Reaction.—$KClO_3 = O_3 + KCl$ (potassium chloride).

In this process the O is obtained from the $KClO_3$, the MnO_2 acting by catalysis (p. 18). KCl is soluble and MnO_2 insoluble in H_2O, hence they may be easily separated.

Exp. 64.—Shake the residue in the tube (when its contents have been exhausted of O) with some H_2O, and pour the mixture on a filter. The solution of KCl passes through and the MnO_2 remains on the filter; when dry it may be used again. Obtain crystals of KCl by evaporation.

By inverting several bottles in the trough and using a sufficient amount of material, O for all the experiments may be prepared at the same time, or the gas may be more conveniently collected in a gas-holder and transferred from this to the bottles for the several experiments.

Illustrations of the Chemical Energy of O.

Producing Flame in O.—*App.*—Lamp. *Mat.*—The O from Exp. 63, and pine splinter pushed through the centre of a disk of pasteboard to serve as a temporary cover.

Exp. 65.—Put the bottle of O erect on a table; light the splinter, and when the end glows, blow out the flame and thrust the glowing end into the gas. The wood will again blaze. Repeat the experiment again and again until the O is exhausted.

Burning of Charcoal in O.—The *App.* and *Mat.* used in preparing O, stout wire with one end bent into a U-shape and the other pushed through the centre of a piece of pasteboard, and piece of charcoal (that prepared from bark being the best).

Exp. 66.—Fill the bottle with O. Fix the C firmly in the U of the wire, heat it to glowing and plunge it into the bottle. The C burns brightly, throwing off brilliant sparks. CO_2 is formed by the combustion.

Burning of Sulphur in O.—*App.* and *Mat.*—The O generator, etc., the U wire with a piece of chalk or crayon containing a deep cavity fitted into the bend (or deflagrating spoon, p. 143), and piece of S as large as a pea.

Exp. 67.—Fill the bottle with O; put the S in the chalk cavity, light it, and thrust it into the gas. SO_2 (p. 53) is formed.

Fig. 14.—Sulphur Burning in O.

Burning of Phosphorus (P) in O.—*App.* and *Mat.*—The O generator, etc., and piece of P as large as a grain of wheat. (See Caution below.)

Caution.—Great care should be taken in using P, as very little friction ignites it and it burns with great energy. It should be cut under H_2O and handled with wet hands. If a piece of P in contact with the hand takes fire, quickly plunge the hand into water.

Exp. 68.—Fill the bottle with O, dry the P with filter paper, put it into the chalk cavity, light it, and plunge it into the gas. The intensity of the chemical energy produces a brilliant light. P_2O_5 (p. 80), the dense white fumes, is formed.

Burning of Iron Wire in O.—*App.* and *Mat.*—The O generator, etc., substituting for the half l. bottle a stoppered l. receiver without bottom (p. 143), and piece of light iron wire (or better, piano wire), half of which is made into a spiral by wrapping it on an iron rod or lead pencil. The coil end of the wire should be hammered very thin, and the straight end pushed through the centre of a piece of pasteboard.

Fig. 15.—Iron Wire Burning in O.

Exp. 69.—Fill the receiver with O and remove it on a saucer to the table. Fix the friction end of a match by means of a slit made in it on the coil end of the wire, or dip the end into melted S, light the match or S and quickly plunge the wire into the gas. It burns with a dense light accompanied by a shower of sparks. Fe_3O_4, which falls off in globules, is formed.

Effect of O Forced into a Flame.—*App.* and *Mat.*—Lamp, blowpipe, piece of iron wire, and O in a bottle gas-holder.

Exp. 70.—Force O into the flame from the gas-holder as air is forced into it in blowpiping, and *to test the temperature of the flame*, hold the iron wire in it. The metal burns with scintillations, like the wire in O.

Uses and Tests.

O is the great life element of animals. From the lungs into which it is breathed as a constituent of air, it is taken up by the blood and distributed through the body, entering into various combinations to nourish the wasted organs and to generate heat. Combining readily with combustible matter, it plays an important part in heating and illumination. It is also the active agent in decay and fermentation. O specially prepared for the purpose, is sometimes used for intensifying the heat of flames.

The rekindling of a glowing splinter (Exp. 65) is a toler-

ably sure evidence of the presence of O. N_2O (p. 73) is the only other gas that will reproduce flame in this way.

Ozone.

Ozone is an allotropic (p. 18) form of O, differing atomically from O in having *three* atoms in its molecule (the molecule of O contains *two* atoms).

Ozone has an odor somewhat like that of weak Cl. It acts with great energy, being a powerful oxidizing agent. It destroys vegetable colors and is an active disinfectant.

Occurrence, Preparation, and Test.

A small quantity of ozone exists in pure air, but more is found in the atmospheres of large cities. In air it probably acts as a purifying agent.

Ozone is developed by the action of an ordinary electrical machine, and can best be prepared by an electrical machine designed for the purpose. It is most conveniently prepared, however, by partly covering a piece of phosphorus (P) with H_2O.

To Prepare Ozone and Show its Presence.—*App.*—Wide-mouthed half l. bottle with cover. *Mat.*—Cylinder of P about an in. long (See Caution, p. 47) white paper, and mixture of starch paste and solution of potassium iodide (KI).

Exp. 71.—Scrape the P clean and put it into the bottle; add sufficient H_2O to half cover it, cover the bottle and let it stand in a warm place for several hours. It will then contain ozone. *Test.*—Smear the paper with the paste mixture and suspend it in the bottle. It quickly becomes blue, the ozone decomposing the KI, the iodine of which colors the starch blue. Ozone is produced by the rapid evaporation of certain liquids.

Ozone by Evaporation.—*Mat.*—KI paper and ether (or alcohol).

Exp. 72.—Let fall a few drops of ether on a piece of the paper and set the liquid on fire. After the combustion the paper will be colored blue from the formation of ozone.

Combining of Oxygen and Hydrogen.

The Oxy-Hydrogen Flame.

The H flame (Exp. 20) is produced by the union of H with O from air. If the O be supplied from a gas holder, a flame of much greater intensity, called the *oxy-hydrogen* flame, is produced. This flame quickly burns steel wire, scattering the glowing mass in a beautiful shower, and it readily melts platinum and other substances that withstand the heat of the hottest blast furnaces. H_2O is produced by this combustion as it is by the ordinary burning of H.

The Oxy-Hydrogen Blowpipe is an apparatus for producing the OH flame. It consists of two tubes, one inside the other. The inner tube is connected with an O gas-holder and the outer with an H gas-holder.

To Explode a Mixture of O and H.—*App.*—Soda-water bottle, clay-pipe, short glass tube, lamp, and long pine splinter. *Mat.*—Some of the H and O mixture in the bottle gas-holder, and some soap-bubble liquid (p. 24) in a mortar (or metal vessel). To prepare the gas mixture, prepare sufficient O to reach to a depth of 3 or 4 inches in the bottle, and add to it twice as much H.

Exp. 73.—Fill the soda-water bottle with the mixture by H_2O displacement, cork the bottle and, holding it in a horizontal position in one hand, uncork it, and quickly insert a lighted match into its mouth. The mixture will explode. Explode a bottle full of the gas by lifting the bottle inverted just out of the H_2O and inserting the lighted match. Explode a bottle with a light body, as a cork, placed just above its mouth.

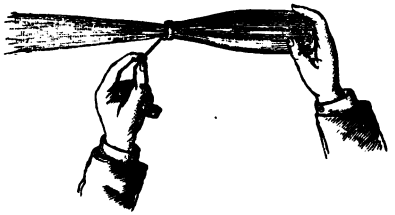

Fig. 16.—Exploding of H and O.

Exp. 74. — Inflate soap-bubbles with the mixture in the same manner as bubbles were inflated with H and have an assistant touch them with the lighted splint. (See Caution below).

Exp. 75.—Replace the pipe by a short glass tube, start the gas, and move the tube through the liquid, which will become covered with bub-

bles. Explode the bubbles by touching them with the lighted splinter. (See Caution below).

Caution.—In making experiments 74 and 75, be very careful not to touch the bubbles with the flame until the delivery tube has been removed a considerable distance from them.

SULPHUR (S) 32.

PROPERTIES.

S has several allotropic forms. Common S is a yellow, crystalline solid, which melts at 114° C. and boils at 440°. Common S, when heated to boiling and suddenly cooled, becomes dark and soft (plastic sulphur). S is insoluble in H_2O, but dissolves readily in carbon disulphide. It burns with a blue flame, SO_2 being formed, (Exp. 83). Compounds of S with metals are called *sulphides.*

TO PREPARE CRYSTALS OF S.—*App.*—Cup 2 in. deep cut from the bottom of a tin fruit can (or an old tea-cup) and lamp. *Mat.*—½ lb. S.

Exp. 76.—Melt the S in the cup, heating so carefully that it does not darken. Then reduce the temperature sufficiently to allow the surface of the liquid to harden, and when a thin crust has formed, make a hole in it and pour out the liquid S remaining. Remove the crust, and the bottom of the cup will be found full of crystals. If a porcelain cup be used, it may be broken to show the crystals. Crystals of S may also be obtained from its solution. (Exp. 78).

FIG. 17.—CRYSTALS OF S.

TO PREPARE PLASTIC S.—*App.*—Small test-tube and holder (p. 142), for which a flattened roll of paper may be substituted, and lamp. *Mat.*—2 g. S and H_2O.

Exp. 77.—Melt the S in the test-tube and continue heating until it boils, then pour it into the H_2O. The dark product, which resembles india rubber, is *plastic* S. Put a piece of plastic S in boiling H_2O, and preserve another piece for several months. They will change to ordinary S.

DISSOLVING OF S IN CARBON DISULPHIDE (CS_2).—*App.*—Small test-tube and piece of window-glass. *Mat.*—CS_2 and piece of S as large as a grain of wheat.

Exp. 78.—Put the S and 2 c.c. of CS_2 in the tube, and shake. The S dissolves. Pour some of the solution on the glass, and crystals of S soon form.

Occurrence and Preparation.

S occurs free in certain volcanic regions. About nine-tenths of the S of commerce comes from Sicily. Valuable deposits are found in Nevada and Louisiana. It is a constituent of many compounds, as hydrogen sulphide, pyrite, and gypsum.

Native S is freed from earthy impurities by distilling the volcanic earth, or, if this be rich in S, by simply heating it and separating the melted S from the impurities.

Uses and Tests.

The chief consumption of S is for H_2SO_4. A large amount is also used in the manufacture of friction matches, gunpowder, and vulcanized rubber. S and its compounds have been used extensively of late years for preventing grape disease in the vineyards of Europe.

S is recognized by its color, and when burned, by its odor and flame. Combined S may be detected by fusing the compound (on charcoal with a blowpipe flame) with sodium carbonate, and placing the fused mass on a clean silver coin. The coin is blackened.

Exp. 79.—Test sodium, magnesium, or calcium sulphate for S.

Hydrogen Sulphide (H_2S).

Properties.

H_2S (sulphuretted hydrogen, hydrosulphuric acid) is a colorless gas with the odor of rotten eggs. At ordinary temperatures H_2O dissolves more than 3 times its volume of the gas, which gives its odor to the solution. It burns with a blue flame, H_2O and SO_2 (p. 53) being produced, and is readily decomposed by heat. Its action on certain metals produces sulphides, and it precipitates many metals as sulphides from solutions of their compounds.

Occurrence and Preparation.

H_2S is a product of the putrefaction of organic substances containing S, and hence one of the causes of the foul odor of

sewers. It is a constituent of the waters of "sulphur springs." It is generally prepared from HCl or H_2SO_4 and iron sulphide (FeS).

To PREPARE H_2S.—*Test.*—*App.*—Test-tube and piece of filter paper. *Mat.*—½ g. FeS, and H_2O, HCl, and solution of lead acetate.

Caution.—H_2S should be prepared in a draft of air or out of doors.

Exp. 80.—Put the FeS in the tube, cover it with H_2O and add a little HCl. H_2S, known by its smell, is given off. The action may be hastened by heating. *Test.*—Wet the paper with the acetate and cover the tube with it. The paper darkens. Write a name on the paper with the acetate and expose it to the gas.

Reaction.—$FeS + 2\,HCl = H_2S + FeCl_2$ (ferrous chloride).

ILLUSTRATIONS OF PROPERTIES.

DISSOLVING OF H_2S IN H_2O.—*App.*—Same as that used for generating H (p. 23). *Mat.*—HCl, 3 or 4 g. FeS, and qr. l. bottle nearly full of H_2O.

Exp. 81.—Put the FeS, a little H_2O, and 2 or 3 c.c. of HCl in the generator, and dip the delivery tube into the bottle of H_2O, extending it to the bottom. H_2S water is formed. Continue the action until the H_2O smells strongly of the gas. Cork the bottle and preserve the solution.

BURNING OF H_2S.—*App.*—The generator used in Exp. 81, jet tube like that used in burning H, and a dry wide-mouthed bottle. *Mat.*—2 or 3 g. FeS and HCl.

Exp. 82.—Connect the jet tube with the end of the delivery tube and generate the gas. After waiting until the air is expelled from the apparatus, light the jet. *To show that H_2O is formed,* hold the wide-mouthed bottle inverted with the flame within it and moisture will collect upon it.

USES AND TESTS.

H_2S is much used in the chemical laboratory in testing for and separating metals. It is known by its odor; a special test is its darkening paper wet with a solution of lead acetate, lead sulphide being formed. (Exp. 80)

Sulphur Dioxide (SO_2).

PROPERTIES.

SO_2 (sulphurous oxide, sulphurous acid) is a colorless, suffocating gas, very soluble in H_2O. It extinguishes flame, and is a bleaching agent. In bleaching, it does not destroy the

color as Cl does, but combines with it to form colorless compounds. Compounds of SO_2 with metallic oxides, etc., are called *sulphites*.

Preparation, and Illustration of Properties.

SO_2 is formed by the burning of S in air, as in the kindling of a sulphur match. It may be obtained pure by the action of strong H_2SO_4 on copper.

Extinguishing of Flame by SO_2.—*App.*—Wide-mouthed half l. bottle with cover, small crucible, wire bent so as to suspend the crucible within the bottle, and lamp. *Mat.*—2 g. S, tuft of cotton fastened to the end of a wire (or pine splinter), and alcohol.

Exp. 83.—Hold the crucible containing the S by means of the wire in the flame until the S kindles, then suspend it in the bottle and put on the cover. When the S flame goes out, remove the crucible, wet the cotton with alcohol, light it and thrust it into the gas. The flame is extinguished.

Bleaching with SO_2.—*App.*—The crucible used in last experiment, an ordinary lamp chimney and lamp. *Mat.*—2 or 3 g. of S and a red flower.

Exp. 84.—Support the flower, moistened with H_2O, in the top of the chimney, then heat the S in the crucible until it kindles, put the crucible on a piece of metal or porcelain, and cover it with the chimney. The flower bleaches.

Uses and Tests.

The most important use of SO_2 is in the manufacture of H_2SO_4. It is also used for bleaching straw and woolen fabrics, and as a disinfectant. The gas is recognized by its odor, that of a burning match.

Sulphur Trioxide (SO_3).

SO_3 (sulphuric oxide) is a white, silky-looking, crystalline solid, with so strong an affinity for H_2O that the two substances combine with a hissing sound, forming H_2SO_4. It may be prepared by passing a mixture of SO_2 and O through a heated tube containing platinum sponge (p. 92) the SO_2 becoming oxidized. The fuming product is condensed in a cooled receiver.

Sulphuric Acid (H_2SO_4).

H_2SO_4 (oil of vitriol) is a colorless, oily liquid with a sp. gr. of 1.82 (sp. gr. of pure acid is 1.84). H_2SO_4 is very corrosive, quickly charring wood and other organic substances, and is intensely acid, reddening litmus paper when diluted with a thousand times its volume of H_2O. It unites with H_2O with great energy, producing much heat. Commercial H_2SO_4 contains lead sulphate formed from the leaden vessels used in the manufacture of the acid, is often colored brown by dust or other matter, and always contains some H_2O. Compounds formed by the action of H_2SO_4 on metals, etc., are called *sulphates*.*

CORROSIVENESS AND ACIDITY OF H_2SO_4.—*App.*—Glass rod, and strip of blue litmus paper. *Mat.*—Pine splinter, piece of white paper, H_2SO_4 and H_2O.

Exp. 85.—Dip the splinter into the H_2SO_4. It quickly blackens. Write on the paper with dilute H_2SO_4 and heat the writing.

Exp. 86.—Stir a drop of H_2SO_4 in 10 c.c. of H_2O and dip the blue paper in the liquid. The paper reddens.

PRODUCTION OF HEAT BY THE COMBINING OF H_2SO_4 AND H_2O.—*Mat.*—60 c.c. strong H_2SO_4, 30 c.c. H_2O in a beaker, and 2 or 3 c.c. alcohol in a test-tube.

Exp. 87.—Pour the H_2SO_4 slowly into the H_2O (H_2SO_4 and H_2O should always be mixed in this way) and stir the mixture with the test-tube. The alcohol will boil.

TO SHOW THAT H_2SO_4 CONTAINS LEAD SULPHATE ($PbSO_4$).—*Mat.*—20 c.c. strong H_2SO_4 and 100 c.c. H_2O in a beaker.

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* Vinegar was the strongest acid known to the ancients. Sulphuric acid is said to have been obtained by Geber, an Arab, in the eighth century, by distilling alum. It was certainly obtained by Basil Valentine, a monk of Erfurt, about the year 1440, by distilling green vitriol. Valentine also made the first steps in the discovery of the present process of manufacturing the acid, which process possessed all its essential features when Dr. Roebuck, of England, introduced the leaden chambers in 1746. Since the production and use of this acid are so universal, it has been suggested that the extent of its manufacture may be regarded as a measure of the material prosperity of a country. *Nitric acid* was known to Geber, who called it *solutive water*. It was distilled from saltpetre (Exp. 131) mixed with clay, etc., in the thirteenth century. *Hydrochloric acid* was occasionally produced at an early date by heating a mixture of common salt and clay; its manufacture from salt and H_2SO_4 (Exp. 48) began about the year 1789.

Exp. 88.—Add the H_2SO_4 to the H_2O and let the mixture stand several hours, when the precipitate of $PbSO_4$ will be found at the bottom of the beaker.

Occurrence and Preparation.

H_2SO_4 is found in the waters of certain springs and rivers in volcanic regions. Its compounds (sulphates, as gypsum) are abundant. H_2SO_4 is formed by the union of SO_2 and H_2O.

To Show How H_2SO_4 is Formed.—*App.*—Wide-mouthed l. bottle, small crucible with suspending wire, and lamp. *Mat.*—2 g. S, shaving attached to the end of a wire, HNO_3, and blue litmus paper.

Exp. 89.—Burn the S in the bottle as in Exp. 67 and put the shaving wet with HNO_3 into the SO_2 formed. O is transferred from the HNO_3 to the SO_2, the action being indicated by the reddish fumes of NO_2. Add a little H_2O and shake the bottle. The liquid is dilute H_2SO_4. Prove its acidity.

The chemical process involved in the manufacture of H_2SO_4 is similar to that explained by the last experiment. It is shown by Fig. 18. A is a large chamber lined with sheet lead and containing a little H_2O. Entering this chamber is a

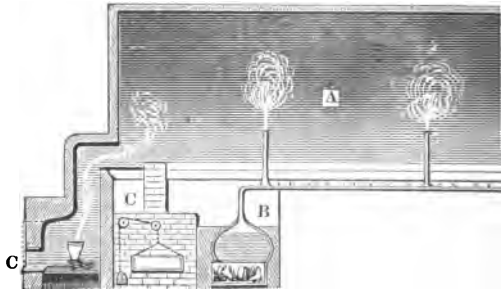

Fig. 18.—Manufacture of H_2SO_4.

stream of SO_2 produced by heating S, or generally iron pyrite (FeS_2) in the furnaces CC; HNO_3 vapor produced from sodium nitrate and H_2SO_4 contained in an iron crucible heated by the SO_2; and steam from the boiler B.

The reactions are thus explained: NO produced from the HNO_3 unites with O, the union forming NO_2. This gives a

portion of its O to SO_2, the union forming SO_3 which unites with H_2O, the union forming H_2SO_4; the NO unites with another portion of O and the action continues. The H_2SO_4, very dilute, forms on the bottom of the chamber. It is condensed by evaporation to the requisite density.

Uses and Tests.

H_2SO_4 is one of our most useful products. It is used in the chemical laboratory, in preparing other acids, bleaching compounds, artificial fertilizers, etc., in refining petroleum, and for many other purposes.

H_2SO_4 is known by its charring organic substances, and a test for the acid, either free or in one of its salts, is the production of a heavy white precipitate with barium chloride ($BaCl_2$). The precipitate is insoluble in H_2O and dilute acids.

Exp. 90.—Add a solution of $BaCl_2$ to very dilute H_2SO_4, also to a solution of sodium sulphate. White precipitates are produced. Try to dissolve them.

The other elements of the S group, which are quite rare, are closely allied to S. *Selenium* possesses the peculiar property of undergoing a change in its power of conducting electricity by the action of light. Selenium and Tellurium occur both free and combined.

PRACTICAL QUESTIONS.

1. Name some compounds containing O. Some that do not contain O.

2. What is the weight of a litre of O? A gallon?

3. How much O can be prepared from 10 g. of $KClO_3$?

4. How much $KClO_3$ would be required to produce 10 g. of O? To produce 1 litre?

5. What other questions may be asked concerning the reaction (p. 47)?

6. The reaction in the preparation of O from HgO (mercuric oxide) is expressed thus:

$$HgO = Hg + O$$

How do the weights of O prepared from equal weights of $KClO_3$ and HgO compare with each other?

7. On what does the amount of O needed by the system depend?

8. During what season of the year do we consume the greatest amount of O? The least amount? Why?

9. What effect would be produced by breathing O instead of air?

10. Why is fruit preserved by canning? Why by drying?

11. Why is S used on the ends of friction matches?

12. $Cu + H_2S = ?$ Explain the reaction.

13. Why is H_2SO_4 blackened by organic matter?

14. How much H_2SO_4 is required to dissolve 100 lbs of Zn?

15. What weight of S must be burned to make 100 litres of H_2SO_4? What weight of FeS_2?

CALCIUM GROUP.

CALCIUM, BARIUM, STRONTIUM, LEAD.

The elements of this group are *dyads*. The oxides of the first three are the so-called *alkaline earths*.

CALCIUM (Ca) 40.

Ca is a reddish, soft, malleable metal, which quickly oxidizes in moist air and decomposes H_2O. Its compounds, the most abundant of which is calcium carbonate (limestone, etc.) are widely diffused.

Calcium Oxide (CaO).

CaO (lime, quicklime) is a white, amorphous, strongly alkaline solid. It combines with H_2O with great energy (slacks) producing much heat. The product is calcium hydrate. It absorbs moisture from the air and crumbles to powder (becomes "air slacked") which gradually absorbs CO_2.

SLACKING OF CaO.—*App.*—Small tin lid. *Mat.*—Lump of CaO as large as a walnut and H_2O.

Exp. 91.—Put the CaO on the lid and pour on it 20 or 30 c.c. of H_2O. It increases greatly in bulk and temperature. *To test the heat* support the lid on the hand and light a match against the slackening CaO.

CaO is prepared by intensely heating limestone ($CaCO_3$) in large kilns or piles. The process is called "burning lime."

The CO_2 is driven off and CaO remains. CaO is used as a fertilizer, as a flux in metallurgy, as an ingredient of mortars and cements, in the manufacture of bleaching powders, and for other purposes. *Hydraulic cement*, which hardens under H_2O, is either lime obtained from limestone containing from 15 to 35 per cent. of clay, or a prepared mixture of ordinary lime and clay.

Ca Hydrate (CaH_2O_2), Ca Chloride ($CaCl_2$).

CaH_2O_2 (slacked lime) is a white alkaline powder slightly soluble in cold H_2O and more soluble in cold than in hot H_2O. The solution is *lime-water*. *Whitewash* is a mixture of CaH_2O_2 and H_2O. *Bleaching powder* (chloride of lime), which is regarded as a mixture of calcium chloride and calcium hypochlorite, is a white powder used in large quantities for bleaching. It is prepared by passing Cl through recently slacked lime.

$CaCl_2$ is a white deliquescent salt, prepared by dissolving calcium carbonate in HCl. It is used for drying gases.

Calcium Carbonate ($CaCO_3$).

$CaCO_3$ (limestone, chalk, marble, etc.) varies in color and varies greatly in structure; marble is white and crystalline, while ordinary limestone is generally blue or gray. Crystalline $CaCO_3$ has a great variety of forms. $CaCO_3$ is soluble in dilute acids and in H_2O charged with CO_2. The white precipitate which often forms in mineral waters exposed to air is due to the precipitation of $CaCO_3$ by reason of the escape of CO_2.

$CaCO_3$ occurs in nature as limestone, chalk, marble, coral reef, etc. Shells are largely $CaCO_3$; whiting is ground chalk. Stalactites and stalagmites are conical masses of $CaCO_3$ found in caverns, the former hanging like icicles from the roof of the cavern, and the latter projecting from the bottom. They are formed by H_2O, charged with CO_2 and holding $CaCO_3$ in solution, trickling through the rocks; CO_2 escapes and $CaCO_3$ is deposited.

Calcium Sulphate ($CaSO_4$).

$CaSO_4$ is a white mineral occurring in both a crystalline and an amorphous condition. The hydrated amorphous variety, $CaSO_4+2\ H_2O$, is known as *gypsum* or plaster. $CaSO_4$ is soluble in about 400 times its weight of cold H_2O. Gypsum, when heated, gives up its H_2O, and if heated to about 120° C. forms a dry product called plaster of Paris, which when made into a paste with H_2O, recombines with the H_2O and becomes hard. This property renders the substance useful for making casts, ornamental designs, etc. Gypsum is much used as a fertilizer. A variety called *alabaster* is cut into vases, boxes, etc. Calcium sulphate is widely distributed and very abundant.

Calcium Phosphate ($Ca_3P_2O_8$).

$Ca_3P_2O_8$ is the chief earthy material of bone, and forms a valuable constituent of the grains of cereals. It also occurs in rocky masses, in North Carolina and other places. It is a valuable fertilizer, forming the most important ingredient of guano and phosphatic fertilizers.

Exp. 92.—Heat a fragment of $CaCO_3$ on charcoal until CaO is formed. Prepare CaCl and $CaSO_4$.

BARIUM (Ba), STRONTIUM, (Sr).

These are rare metals which closely resemble Ca, and most of their compounds are closely analogous to Ca compounds. The salts of Ba color a flame green, and those of Sr, crimson, hence the extensive use of these salts in pyrotechny. Barium sulphate, which is sometimes found as a heavy white mineral, is used for adulterating white lead.

Colored Fires.—*App.*—A brick (or piece of earthenware). *Mat.*—2 g. barium nitrate ($BaNO_3$), 2 g. strontium nitrate ($SrNO_3$), 1 g. potassium chlorate ($KClO_3$) and 1 g. gum shellac (or charcoal); these must be finely pulverized and very dry.

Exp. 93.—*Green fire.* Mix thoroughly with care, the $BaNO_3$, half the $KClO_3$, and half the shellac, put the mixture on the brick, and set it on fire with a match. The burning of the shellac (carbon) is sustained by the O of the nitrate and chlorate, and the Ba produces the green color.

Exp. 94.—*Red fire.* Mix the $SrNO_3$ with the remainder of the $KClO_3$ and shellac; and set the mixture on fire. The action in burning is the same as that in producing green fire.

LEAD (Pb) 206.9.

Pb is a bluish-white, malleable metal, and so soft that it can be easily cut and indented. Sp. gr. 11.5. When freshly cut, it has a bright lustre which it soon loses by oxidation. Natural waters act upon Pb; those, however, containing carbonates, sulphates, or phosphates, have but little action on it. Since the salts of lead are poisonous, the conveyance of water for household purposes through lead pipes is often dangerous. Water that has been *standing* in lead pipes should not be used for drinking or culinary purposes. Pb is slightly acted on by cold HCl and H_2SO_4; it is soluble in HNO_3.

Pb is rarely found free in nature. Its most abundant ore is the sulphide (PbS, Galena) from which it is generally obtained by roasting the ore in an opened reverberatory furnace, and then heating it to a higher temperature with the furnace closed. Pb is used for water pipes, for the chambers employed in the manufacture of H_2SO_4, and various other purposes. It is an ingredient of several alloys: common solder and pewter are Pb and tin; type-metal, Pb and tin, or Pb, tin, and antimony.

Exp. 95.—Find the sp. gr. of Pb (p. 133.) *Exp.* 96.—Test the solubility of Pb in acids.

Compounds.

Lead monoxide (PbO, litharge) is a reddish or yellowish powder, generally prepared by heating Pb in air. It is used as an ingredient of flint glass and in the preparation of paint. **Lead dioxide** (PbO_2) is a brown powder prepared by oxidizing litharge. **Red lead** (minium) is a mixture of PbO and PbO_2. **Lead sulphide** (Galena) is artificially produced as a black or brown precipitate by passing hydrogen sulphide into solutions of Pb. **Lead acetate** (sugar of lead) is a white, poisonous salt, soluble in H_2O. **Lead silicate** is an important ingredient of

flint glass. **White lead** is a mixture of lead carbonate and lead hydrate. It is prepared in large quantities for paint by the action of vinegar on sheet lead in jars covered with spent tan. The lead acetate first formed is converted into a carbonate by the action of CO_2 from the decomposing tan. The disease called painter's colic is due to the slow action of lead carbonate. Epsom salt is an antidote for lead poisons.

TESTS.

Pb compounds yield Pb when fused with sodium carbonate on charcoal. H_2SO_4 produces in solutions of salts of Pb a white precipitate of lead sulphate.

Exp. 97.—Obtain a globule of Pb from lead acetate. Dissolve it in HNO_3 and add H_2SO_4.

MAGNESIUM GROUP.

MAGNESIUM, ZINC, CADMIUM.

The elements of this group are *dyads*. Each of them has only one oxide and one sulphide.

MAGNESIUM (Mg) 24.

Mg is a silver-white metal which tarnishes in air, and when heated, burns with great brilliancy. It dissolves in the common acids. Mg is not found free in nature, but is widely diffused as a constituent of a variety of minerals and of natural waters. The salts of Mg give water a bitter taste. Mg is generally prepared by heating magnesium chloride with sodium. It is used as a source of light, for which purpose it is sold in the form of ribbon or wire.

TO SHOW THE Mg LIGHT.—*App.* Lamp and pincettes. *Mat.*—2 or 3 in. Mg ribbon.

Exp. 98.—Make this experiment if possible in a darkened room. Hold one end of the ribbon by means of the pincettes in the flame, and the metal will soon burn. The white ash is MgO.

Compounds.

Magnesium oxide (MgO, magnesia) is a white, infusible powder formed when Mg burns in air. **Magnesium carbonate**

($MgCO_3$) occurs as a mineral and is also prepared. **Magnesium sulphate** ($MgSO_4$) is a white salt soluble in H_2O. Its solution produces crystals called *Epsom salt* ($MgSO_4 + 7\ H_2O$) which is found in many mineral waters. **Magnesia alba** is a mixture of the carbonate and hydrate (MgH_2O_2). It is prepared by adding sodium carbonate to a hot solution of $MgSO_4$.

Exp. 99.—Prepare $MgSO_4 + 7\ H_2O$ from H_2SO_4 and $MgCO_3$. Prepare also magnesia alba.

ZINC (Zn) 65.

Zn is a bluish-white, hard, crystalline metal. It is brittle at ordinary temperatures and at temperatures above 200° C., but malleable at from 100° to 150°, which property renders it capable of being rolled into sheets. It tarnishes in moist air, and when strongly heated burns with a greenish-white flame. It readily dissolves in dilute acids, and precipitates many metals from solutions of their salts.

Exp. 100.—Show the burning of Zn by heating a bit of the metal in a blowpipe flame. *Exp.* 101.—Test the solubility of Zn in acids.

THE LEAD TREE.—*Mat.*—Solution of lead acetate in a small beaker (or wide-mouthed bottle), and strip of Zn.

Exp. 102.—Brighten the Zn, bend it into a U-shape, and suspend it in the solution by means of a pencil or match placed across the top of the beaker. Allow the beaker to stand undisturbed for several hours. Pb forms on the Zn in metallic flakes, the enlarging mass resembling a vegetable growth. In this action the Pb and Zn change places, zinc acetate being formed, and the weights of Zn dissolved and Pb precipitated are proportional to the atomic weights of these elements.

Zn is not found free in nature, but its ores are quite abundant. The most important of these are the sulphide (blende), carbonate (calamine) and oxide (red oxide). The metal is obtained from its ores by roasting them and then heating the product, zinc oxide, with charcoal, when Zn is set free, and collected in a receiver.

Zn is used for coating (galvanizing) iron, for the plates of voltaic batteries, and, in the form of sheets, for various purposes. It is used also as an ingredient of brass and German silver.

Compounds.

Zinc oxide (ZnO) is an ore, and is also prepared in the form of a light white powder by burning Zn vapor at the mouth of the furnaces in which the ores are reduced. It is much used as an ingredient of white paint. **Zinc chloride** ($ZnCl_2$) is a white deliquescent substance prepared by dissolving Zn in HCl. It is used in soldering, preserving anatomical specimens, etc. **Zinc sulphate** ($ZnSO_4$) is prepared by dissolving Zn in H_2SO_4. Its solution produces crystals called *white vitriol* ($ZnSO_4 + 7\ H_2O$). It is used in medicine and in dyeing.

Exp. 103.—Prepare ZnO, $ZnCl_2$ and $ZnSO_4 + 7\ H_2O$.

Cadmium is a bluish-white metal found in certain Zn ores. Its oxides and hydrates resemble those of Zn. The sulphide is much used as a yellow paint.

ALUMINUM GROUP.

ALUMINUM, INDIUM, GALLIUM, GLUCINUM, CERIUM, DIDYMIUM, LANTHANUM.

ALUMINUM (Al) 27.

Al is a bluish-white, very light, sonorous metal. It is not found free in nature, but as a constituent of clay, slate, marl, and many other compounds, is very abundant. It has been too expensive for many uses to which it is adapted, but by reason of an improved process of preparing it recently discovered, its cost will doubtless be greatly reduced and its uses increased. It has been employed mainly in making certain philosophical instruments, and as an ingredient of aluminum bronze (Al and copper) a hard golden alloy, of which much cheap jewelry is made.

Al Oxide (Al_2O_3), Al Hydrate ($Al_2H_6O_6$).

Al_2O_3 (alumina) occurs native, as corundum, of which the ruby and sapphire are varieties; and in an impure form, as emery. It may be prepared as a white powder by heating ammonia alum.

$Al_2H_6O_6$ is a white gelatinous mass, which may be obtained

by adding $(NH_4)HO$ to a solution of alum. It combines with certain organic coloring substances, producing lakes which are used as pigments, and which in dyeing are formed within the fibres of the material.

To Prepare Logwood Lake.—*Mat.*—Solution of extract of logwood and solution of alum in test-tubes, and $(NH_4)HO$.

Exp. 104.—Mix the solutions and add $(NH_4)HO$. Logwood lake is precipitated. Prepare also carmine lake.

Aluminum Sulphate ($Al_2(SO_4)_3$).

$Al_2(SO_4)_3$ is a white crystalline substance. It is prepared on a large scale by heating clay with H_2SO_4 and from the aluminum sulphate and silica (alum cake) formed, dissolving out the sulphate with H_2O. It is used as a source of other Al compounds and in dyeing.

Alum.—The term alum is applied to a group of double salts which are crystallizable and soluble in H_2O. The two common alums—ammonia alum ($Al_2(SO_4)_3 + (NH_4)_2SO_4 + 24\ H_2O$) and potash alum—are manufactured in large quantities from a slaty clay by roasting it, leaching the roasted mass with H_2O, and adding, after concentration, potassium or ammonium sulphate. The alum crystallizes from the solution. Alums are used extensively as mordants in dyeing.

Aluminum Silicate.

Aluminum Silicate occurs combined with other silicates in various minerals, and forms the chief ingredient of clay, which contains also silica, iron, and other substances. The plasticity of clay when moist, and the hardness it assumes when heated, render it a highly valuable material.

Bricks, *earthenware*, and *common pottery*, are made of clay rendered plastic with H_2O, then moulded, dried, and intensely heated. Earthenware is glazed by dipping the article into a readily fusible mixture (one of the principal ingredients of which is generally lead oxide), drying and reheating it. *Porcelain*, which is distinguished from earthenware mainly by its compactness and translucency, is made of *kaolin*, a very pure clay, and is glazed with powdered feldspar. The red color of bricks and common pottery is due to iron contained in the clay.

The other elements of the Al group are rare. *Indium* is softer than lead. When heated it gives a violet-blue flame. It is found in the zinc blende of Freiberg. *Gallium* possesses the remarkable property of melting at 30.1° C., and remaining liquid when its temperature falls considerably below the melting point. It is found in zinc ores. *Glucinum*, also called *beryllium* (Be), resembles aluminum. It is found in a few rare minerals. Its salts have a sweet taste.

COPPER GROUP.

COPPER, MERCURY.

COPPER (Cu) 63.

Cu is a reddish, tenacious, very malleable, ductile metal, and one of the best conductors of heat and electricity. Sp. gr. 7.9. Its vapor burns with a characteristic green flame. At ordinary temperatures it is only slightly affected by air or by most acids. Its best solvent is dilute HNO_3.

Cu occurs free in nature, and it is sometimes found in large masses, as in the Lake Superior region. Its most important ore is copper pyrites ($CuFeS_2$) which is widely distributed. By a process of roasting and melting, the iron is separated from the ore, and copper subsulphide remains; Cu is obtained from this by heating it in a current of air. Cu is used for various domestic utensils, for wires to conduct electricity, for coating the bottoms of ships, and other purposes. It is an ingredient of brass (Cu and zinc), German silver (Cu, zinc, and nickel), bronze, gun-metal and bell-metal (Cu and tin), and other alloys.*

* The very early eras of the human race were denoted by the substances used for domestic implements, and were called *ages*, as the "age of stone," the "age of iron," etc. The age of copper followed that of stone and preceded that of iron, which fact shows that copper was known at a very remote period. Tin must also have been long known, since it is found alloyed with ancient copper.

Oxides of Copper.

Copper suboxide (Cu_2O, cuprous oxide) occurs in nature in ruby-red crystals, and is also prepared. It is used to color glass red. **Copper monoxide** (CuO, cupric oxide, black oxide) is a black powder prepared by heating Cu in a current of air, or by roasting the nitrate. It is used to color glass green.

To Form Cu_2O and CuO.—*App.*—Lamp and light wire 6 in. long. *Mat.*—Copper cent and H_2O.

Exp. 105.—Hold the cent in the flame by means of the wire clamped tightly around its edge, and when it becomes quite hot put it in the H_2O. It is covered with red Cu_2O. Hold it again in the flame, keeping it in the outer (oxidizing) part, and the Cu_2O changes to black CuO.

Copper Sulphate ($CuSO_4$), Copper Acetate.

$CuSO_4$ is formed by dissolving Cu in hot H_2SO_4, or CuO in dilute H_2SO_4. Its solution produces crystals called *blue vitriol*, ($CuSO_4 + 5\ H_2O$) the blue color of which is due to the H_2O. Blue vitriol is used in calico printing, and for various other purposes.

To Show that the Color of Blue Vitriol is Due to H_2O.—*App.*—Crucible lid, pincettes, mortar, and lamp. *Mat.*—1 or 2 g. blue vitriol.

Exp. 106.—Powder the vitriol and heat it on the lid. It will become white. Now add a few drops of H_2O and the color will reappear.

Copper acetate (verdigris), is prepared by packing plates of Cu between woolen cloths soaked in vinegar. The term verdigris is sometimes incorrectly used to designate the green carbonate that forms on Cu exposed to moist air.

Exp. 107.—Find the sp. gr. of Cu. *Exp.* 108.—Test the solubility of Cu. *Exp.* 109.—Prepare $CuSO_4 + 5\ H_2O$.

Tests.

Cu is known by the color which it gives to a flame. Ammonium hydrate produces in solutions of Cu a light green precipitate, which dissolves in excess of the hydrate, the liquid becoming deep blue. Clean iron placed in a solution of Cu is quickly coated with the metal.

Exp. 110.—Hold a piece of light Cu wire in a flame. *Exp.* 111.—Add

(NH_4) HO to a solution of copper sulphate. *Exp.* 112.—Dip a knife blade or nail wet with HCl into a solution of blue vitriol to which a little HCl has been added.

MERCURY (Hg) 200.

Hg is a silver-white, lustrous metal, and the only metal liquid at ordinary temperatures. Sp. gr. 13.6. It freezes at —40° C., becoming a malleable and ductile solid. Pure Hg does not change in air at ordinary temperatures. Hg dissolves readily in HNO_3.

Small quantities of Hg are found free in nature. Its principal ore is the sulphide (HgS, cinnabar) which occurs most abundantly in California, Spain, and Austria. More than half the entire amount of the metal consumed is supplied by California. Hg is obtained by roasting the HgS, the S of which combines with O, the union forming SO_2, and the Hg vapor is condensed. Hg is used in the construction of certain meteorological and other scientific instruments, in extracting gold and silver from their ores, as an ingredient of the amalgam of looking-glasses, and as a source of Hg compounds.

Compounds.

Mercury monoxide (HgO, mercuric oxide, red precipitate) is a red crystalline powder or yellow amorphous powder. The former may be prepared by heating Hg in air. HgO is the compound from which O was first obtained. **Mercurous chloride** (Hg_2Cl_2, calomel) is a white crystalline powder, insoluble in H_2O. It may be prepared by heating a mixture of $HgCl_2$ and Hg. It is much used in medicine. **Mercuric chloride** ($HgCl_2$, corrosive sublimate) is a white, crystalline, very poisonous solid, soluble in H_2O. Its best antidote is the white of eggs, with which it forms an insoluble compound. It is prepared by heating a mixture of mercuric sulphate and common salt. It is used to prevent the decay of specimens in natural history.

Tests.

Hg salts yield Hg when heated with dry sodium carbonate. The metal is deposited upon copper placed in solutions of its salts.

Exp. 113.—Heat a little $HgCl_2$ with some dry sodium carbonate in a small test-tube. Globules of the metal form on the sides of the tube.

Exp. 114.—Put a piece of brightened copper wire in a solution of $HgCl_2$, and when it becomes covered with a white coating (Hg), dry it, and heat it in a piece of glass tubing. Globules of Hg form on the glass.

NITROGEN GROUP.

NITROGEN, PHOSPHORUS, ARSENIC, ANTIMONY, BISMUTH, VANADIUM, URANIUM, COLUMBIUM, TANTALUM.

The elements of this group generally act as *triads* or *pentads*. The chemical energies of the first five are, broadly considered, inversely as their atomic weights.

NITROGEN (N) 14.

Properties.

N is a transparent, colorless, odorless gas, a little lighter than air. It does not burn, extinguishes flame, and destroys life by suffocation. It is characterized by weak affinities, and hence many of its compounds, as gunpowder, nitro-glycerine, etc., are very unstable.

Occurrence and Preparation.

N is abundant. It constitutes four-fifths of the volume of air, is one of the chief constituents of animal substance, is present in vegetable substance, and forms a part of many inorganic compounds. It is generally prepared by burning the O from a confined portion of air with phosphorus (P).

To Prepare N.—*App.*—Wide-mouthed l. bottle, short cork that will easily slip inside of the bottle, small piece of chalk containing a cavity (or a small crucible), and saucer (or other shallow vessel). *Mat.*—Piece of P twice as large as a grain of wheat (see Caution, p. 47) and H_2O.

Exp. 115.—Put H_2O in the saucer, place the cork upon it, and support the chalk on the cork; then put the P in the cavity, light it, and quickly cover it with the bottle. A few bubbles of air will at first be driven out by the heat, but H_2O will soon begin to rise, and will finally occupy a part of the bottle equal to the volume of the O consumed. The white fumes of P_2O_5 (p. 80) become absorbed by the H_2O, and N in an impure state remains. Preserve the N in the inverted bottle for Exp. 116.

Extinguishing Flame by N.—*App.*—Tuft of cotton fastened to one end of a wire (or pine splinter). *Mat.*—The N from Exp. 115, and alcohol.

Exp. 116.—Cover the bottle containing N, leaving the H_2O in it, and put it erect on the table; wet the cotton with alcohol, light it, and thrust it into the gas. The flame is extinguished.

Uses and Test.

The N of air serves to dilute the O and render it less energetic, since in respiration, combustion, and other processes none of the N of the utilized air enters into combination. Free N is known by its chemical inertness.

Ammonium (NH_4).

The radical called Ammonium, which is regarded as a metal, has not been isolated, but is supposed to exist from a resemblance of the structure of compounds into which NH_3 enters to the structure of the compounds of potassium and sodium. Thus:

$$NH_3 + HCl = NH_4Cl \text{ (like NaCl and KCl).}$$

Ammonia (NH_3), (NH_4) *Hydrate* (NH_4)*HO*.

Properties of NH_3.

NH_3 is a transparent, pungent, strongly alkaline gas, much lighter than air. It is very soluble in H_2O, one volume of H_2O at 0° C. dissolving more than 1000 volumes of the gas. This solution is called ammonium hydrate (ammonia water, aqua ammonia, solution of ammonia, (NH_4)HO) and exhibits the properties of the gas. NH_3 readily changes red litmus paper blue, and neutralizes the most powerful acids. By

pressure and cold, NH_3 may be condensed to a liquid, which will rapidly evaporate, producing great cold.

DISSOLVING OF NH_3 IN H_2O.—*App.*—Half-l. flask, test-tube that will slip inverted into the flask, bit of red litmus paper, retort stand with wire gauze, and lamp. *Mat.*—$(NH_4)HO$ and large beaker of H_2O.

Exp. 117.—Support the flask inverted in a ring of the stand, and stick with H_2O the litmus paper on its mouth. Put about 10 c.c. of $(NH_4)HO$ in the tube, support the tube on the gauze as shown in Fig. 18, and heat. NH_3 is driven from its solution into the flask. When the flask is full, indicated by the color of the paper changing to blue, remove it carefully, and dip its mouth into the H_2O in the beaker. The H_2O will absorb the gas and rise, finally nearly filling the vessel.

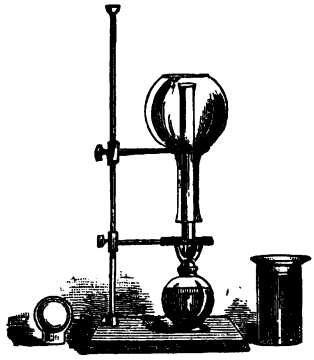

FIG. 18.—DISSOLVING OF NH_3 IN H_2O.

NEUTRALIZATION OF AN ACID BY NH_3.—*App.*—Beaker, stirring rod, narrow strip of blue litmus paper, and piece of broadcloth. *Mat.*—H_2SO_4, $(NH_4)HO$, and H_2O.

Exp. 118.—Put some H_2O in the beaker, add to it a few drops of H_2SO_4, and stir. Touch the liquid with one end of the paper, and the color will change to red. Add a few drops of $(NH_4)HO$, stir, and test again (tear off the paper that has been in the liquid), and continue the operation until the paper is no longer reddened. Ammonium sulphate is produced.

Exp. 119.—Drop H_2SO_4 on the cloth. Red spots are made where the acid touches it. Add $(NH_4)HO$ and the color is restored. H_2SO_4 spots may be removed from clothing in this way.

OCCURRENCE AND PREPARATION.

NH_3 occurs in small quantities in air. It is a product of the decomposition of organic matter containing N, and was formerly produced by the distillation of animal refuse, as hoofs, horns, etc. The name "hartshorn" was given to it from the fact that horns of the deer were often distilled to produce it. The chief source of commercial ammonia is the

ammoniacal liquor of gas-works. This is the liquid produced by passing the illuminating gas, in purifying it, through H_2O. NH_3 is conveniently prepared from ammonium chloride (NH_4Cl) and slacked lime (CaH_2O_2).

To Prepare NH_3 and $(NH_4)HO$.—*App.*—Qr.-l. flask with cork and delivery tube, retort stand, lamp, and mortar. *Mat.*—5 g. NH_4Cl, 10 g. freshly slacked lime, and H_2O in a small bottle.

Exp. 120.—Powder the NH_4Cl and CaH_2O_2, mix them together, put the mixture into the flask and heat gently. NH_3, known by its smell, is given off. *Exp.* 121.—Support the flask, arrange to pass NH_3 through the H_2O in the bottle, and heat. $(NH_4)HO$ is produced.

Reaction.—$2\ NH_4Cl + CaH_2O_2 = 2\ NH_3 + 2\ H_2O + CaCl_2$ (calcium chloride).

Uses.

$(NH_4)HO$ is a valuable laboratory reagent, and is employed in the preparation of many commercial products, as sodium carbonate, indigo, and the aniline colors. Liquid NH_3 is used in the manufacture of ice.

Ammonium Chloride (NH_4Cl).

NH_4Cl (sal ammoniac) is a white crystalline salt, very soluble in H_2O. It is prepared in large quantities by neutralizing the ammoniacal liquor of gas-works with HCl. It is used in soldering, dyeing, and as a source of other NH_4 compounds.

NH_4Cl Fumes.—*App.*—Two beakers (or tumblers) with rims of the same diameter. *Mat.*—$(NH_4)HO$ and HCl.

Exp. 122.—Rinse out one beaker with HCl, the other with $(NH_4)HO$ and invert the acid beaker on the other, fitting the mouths together. The vessels will fill with NH_4Cl fumes. Uncork the $(NH_4)HO$ and HCl bottles, and bring their mouths near together, and the fumes will also appear.

Other NH_4 Compounds.

Ammonium carbonate of commerce is a white, fibrous substance, with a strong smell of NH_3. It is prepared either by heating NH_4Cl with calcium carbonate, or by the dry distillation of animal substance, as bone and horn. There are several ammonium carbonates. **Ammonium nitrate** $(NH_4)NO_3$, is a white crystalline salt, very soluble in H_2O. It is pre-

pared by neutralizing dilute HNO_3 with $(NH_4)HO$ or a solution of ammonium carbonate, and evaporating. It is used in the preparation of laughing gas.

Exp. 123.—Prepare crystals of NH_4Cl, of $(NH_4)NO_3$, and of ammonium sulphate.

TESTS.

NH_4 compounds, when heated with sodium or potassium hydrate, or slacked lime, give off NH_3, known by its smell or by the fumes produced with HCl. Most NH_4 compounds are volatile at moderate temperatures.

Exp. 124.—Heat a solution of NH_4Cl with a solution of sodium hydrate in a test tube. To show by the HCl test that NH_3 is given off, hold a glass rod wet with HCl in the tube.

Nitrogen Monoxide (N_2O).

N_2O (nitrous oxide, nitrogen protoxide, laughing gas), is a colorless, odorless gas, somewhat soluble in H_2O. When pure it may be inhaled without danger. The effect of inhaling a small quantity is a kind of intoxication, that of a larger quantity, insensibility to pain. By pressure and cold it may be condensed to a colorless liquid, in which form it is sold as an anæsthetic. It is an active supporter of combustion, the burning of substances in it being almost as energetic as in O. N_2O is prepared by heating ammonium nitrate, $(NH_4)NO_3$.

TO PREPARE N_2O AND SHOW SOME OF ITS PROPERTIES.—*App.*—The apparatus used in preparing O (Exp. 63). *Mat.*—3 g. $(NH_4)NO_3$ and pine splinter. *Exp.* 125.—Arrange to collect the gas over H_2O. Put the $(NH_4)NO_3$ in the tube, and heat. Fill the bottle with the gas. *Exp.* 126.—To show the solubility of N_2O in H_2O, mark the height of the H_2O in the bottle, and let the bottle stand inverted in the trough for several hours. The H_2O will rise above the mark.

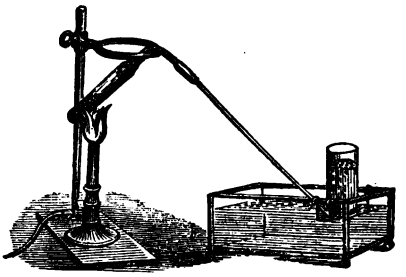

FIG. 19.—PREPARATION OF N_2O.

Exp. 127.—To show that N_2O supports combustion, cover the bottle, place it erect upon the table, and put one end of the splinter, burned to glowing, into it.

Reaction.—$(NH_4)NO_3 = N_2O + 2\ H_2O$.

N Dioxide (N_2O_2 or NO), N Tetroxide (N_2O_4 or NO_2).

NO (nitric oxide) is a transparent, colorless gas, characterized by its strong affinity for O, with which it forms NO_2. It is best prepared from HNO_3 and copper (Cu).

To Prepare NO and Show its Affinity for O.—*App.*—The apparatus used in preparing N_2O. *Mat.*—2 or 3 g. Cu filings (or wire) and HNO_3 and H_2O.

Exp. 128.—Arrange to collect the gas over H_2O, put the Cu in the generator, add some H_2O and HNO_3 to it, and heat. Fill the bottle with the gas. *Exp.* 129.—Lift the bottle from the trough, and NO_2 fumes are formed from the combination of NO with O of the air.

NO_2 (nitrogen peroxide) is a brownish-red gas readily dissolved by H_2O. It is formed by the action of HNO_3 on metals, etc. It is best prepared by the union of two volumes of NO with one volume of O.

Nitric Acid (HNO_3).

Properties.

HNO_3 (aqua fortis) is a fuming liquid, colorless when pure, but usually slightly colored from partial decomposition. Sp. gr. 1.52. It is highly corrosive, and is a powerful oxidizing agent. Its oxidizing action on organic matter often produces a deep yellow stain. It dissolves all the common metals but gold and platinum, and converts cotton, glycerine, and other organic products into highly explosive substances. Compounds formed by the action of HNO_3 on the metals, etc., are called *nitrates.*

HNO_3 as a Solvent.—*App.*—6 small test tubes and lamp. *Mat.*—Small quantities of iron, copper, zinc, lead, mercury, and gold leaf, and HNO_3 and H_2O.

Exp. 130.—Put the metals in the tubes, add to each a few drops of H_2O and a little HNO_3, and heat. All but the gold dissolve.

Occurrence and Preparation.

HNO_3 is not found free in nature. Its principal sources are potassium nitrate (KNO_3, saltpetre), found in India and other tropical regions, and sodium nitrate ($NaNO_3$, soda saltpetre), found abundantly in Peru and Nevada. It is prepared from one or the other of these nitrates (commercially from $NaNO_3$) and H_2SO_4.

To Prepare HNO_3.—*App.*—Distilling apparatus, etc. (p. 27) and mortar. *Mat.*—10 g. KNO_3 or $NaNO_3$ and H_2SO_4.

Exp. 131.—Powder the nitrate, put it in the retort, and add to it sufficient H_2SO_4 to make a thin paste, then arrange the apparatus for distilling, and heat. Continue heating until the reddish fumes, which appear at first and then disappear, are again formed. Preserve the HNO_3 in a glass-stoppered bottle, and allow the retort to cool. When the acid is prepared in large quantities, retorts of cast iron and receivers of earthenware are used.

Reaction.—$KNO_3 + H_2SO_4 = HNO_3 + HKSO_4$ (hydrogen potassium sulphate).

Exp. 132.—Prepare crystals of $HKSO_4$ by heating the residue, after the retort has become cold, with H_2O, filtering and letting the filtrate stand.

Uses and Tests.

HNO_3 is much used in the chemical laboratory. It is used also in dyeing, in making nitro-glycerine, H_2SO_4, and the nitrates, also for etching on metals, and for many other purposes.

To Etch with HNO_3.—*App.*—Piece of brass or iron and common pin. *Mat.*—Bees-wax and HNO_3.

Exp. 133.—Coat the metal or part of it with wax, with the pin write a name through the wax, and wet the writing with HNO_3. After the acid has acted for a few minutes, clean the surface and the name will appear. Names may be written in acid, and hence etched, with a glass tube, one end of which is reduced to a point with a small opening.

HNO_3 is known by the red fumes produced when it acts on certain metals (Exp. 130), and by changing the colors of certain organic substances to yellow. The nitrates deflagrate when heated on charcoal.

Exp. 134.—Make the tests for HNO_3 above indicated, using a piece of copper wire, a piece of quill, and potassium nitrate.

Air (O, N, etc.)

Properties.

Air is the invisible gas that surrounds us. When pure it is transparent, colorless, and odorless. It exerts a pressure of about 15 pounds to the square inch (at the level of the sea) on the earth's surface. The weight of 100 cubic inches is about 31 grains.

Composition of Air.

Air is composed mainly of a *mixture* of O and N, the percentage composition being:

	By Measure.	*By Weight.*
O	20.9	23.1
N	79.1	76.9
	100.0	100.0

It contains also a small quantity of CO_2, a trace of ammonia, and a variable amount of H_2O vapor, sometimes in a gaseous form and sometimes in the form of clouds. The composition of air may be approximately determined by consuming its O with phosphorus (P).

To Analyze Air.—*App.*—Large test-tube, and strip of light cardboard 2 in. long and ¼ in. wide. *Mat.*—Piece of P (see Caution, p. 47) twice as large as a grain of wheat, and H_2O in a saucer.

Exp. 135.—Bend the cardboard into a U-shape, put the P in the bend, and slip the strip with the P into the test-tube inverted. Then support the tube with its mouth under H_2O. Mark the height of the H_2O within the vessel, and let the apparatus stand 24 hours. The O combines with the P, forming P_2O_3 (p. 80) which is absorbed by the H_2O, and H_2O rises and occupies a volume of the vessel equal to that of the O. Measure the height of the H_2O; this is about one-fourth of the height of the tube.

To Show that Air Contains CO_2.—*App.*—The blower (p. 136), glass tube 6 in. long, and piece of window glass. *Mat.*—Lime water in a beaker.

To prepare lime water, stir well 15 or 20 g. of quicklime with half a

litre of H_2O and filter. The clear filtrate is lime H_2O. When CO_2 comes in contact with this liquid, a white precipitate of calcium carbonate ($CaCO_3$, chalk) is produced.

Exp. 136.—Connect the glass tube with the blower as the blowpipe is connected with it, dip the tube in lime H_2O, and start the H_2O in the blower. The air bubbles through the liquid, which becomes milkwhite. The precipitate is noticeable only after the passage of a large amount of air. Air may be forced through the lime H_2O with a pair of bellows, to the nozzle of which a rubber tube is attached.

Exp. 137.—Pour a little lime H_2O on the glass, and in a few minutes a film of $CaCO_3$ will cover it. Let the liquid evaporate to dryness and there will be a spot of $CaCO_3$ on the glass.

Permanence and Purity of the Air.

The principal gases of the air are unchangeable except under very extraordinary conditions. O liquefies when subjected to a pressure of 320 atmospheres at —140° C., and N under a pressure of 200 atmospheres at 13° C. The purity of the air is preserved by gaseous diffusion, all its gases mingling with one another to produce a uniform mixture.

PHOSPHORUS (P) 31.

Properties.

P is a wax-like solid, colorless and almost transparent when freshly prepared, but becoming brownish and opaque, especially when exposed to light. Sp. gr. 1.8. It is insoluble in H_2O, somewhat soluble in petroleum and other oils, and very soluble in carbon disulphide (CS_2). It melts at 44° C. and kindles below the boiling point of H_2O, burning with great energy; the product of the combustion is P_2O_5. The extreme combustibility of P renders it necessary to keep it under H_2O and handle it with great care. (See Caution, p. 47.)

P combines slowly with O of the air at ordinary temperatures, P_2O_3 being formed, and emits a faint light visible in the dark, called *phosphorescence*. Phosphorescence is illustrated by the glowing line of light seen when a match is struck on a wall in the dark.

Solubility and Inflammability of P.—*App.*—Small test-tube, beaker,

crucible, piece of filter paper, retort stand, and block of wood. ***Mat.***— 4 pieces of P, each about half as large as a grain of wheat, CS_2 and olive oil.

Exp. 138.—Dissolve a piece of P in 2 or 3 c.c. of CS_2, put the filter paper on a ring of the stand, and pour the solution on it. The evaporation of the liquid leaves on the paper a thin film of P which bursts into flame.

Exp. 139.—Dissolve by heating gently a piece of P in 2 or 3 c.c. of olive oil, rub some of the solution on the hands or face, and go into a dark room. The surface rubbed is luminous.

Exp. 140.—Boil some H_2O in the beaker, and put on it the crucible containing a piece of P. The P will ignite.

Exp. 141.—Rub a piece of P on the block with the end of a lead pencil. It will ignite.

Red phosphorus is an allotropic form of P. It is prepared by heating ordinary P for several hours at a temperature of about 240° C. in an atmosphere of some inert gas, as CO_2. This treatment changes completely the properties of the substance, for red P has a sp. gr. of 2.14, is insoluble in CS_2 and does not take fire at ordinary temperatures. At a temperature a little above 240° C. it changes into common P.

Luminous paint is a mixture applied to surfaces to render them luminous. The phosphorescent substance (the method of its manufacture is a secret), the chief ingredient of which is calcium sulphide, is mixed with suitable oils or varnishes, and these are applied as ordinary paints. Surfaces coated with the mixture, after being exposed to light, are sufficiently luminous to render objects about them visible. Luminous paint will doubtless come into extensive use for coating clock and watch dials, buoys, divers' suits, etc. The mixture may also be combined with such substances as celluloid, papier mache, etc., to render articles made of these substances luminous.

Occurrence and Preparation.

P abounds in nature as a constituent of calcium phosphate (the chief earthy constituent of bone), and of various other compounds. There are about 1¾ pounds of P in the body of an adult person.

P is prepared from various mineral calcium phosphates. The phosphate is first completely decomposed with H_2SO_4,

calcium sulphate ($CaSO_4$) and phosphorus pentoxide (P_2O_5) being formed. The $CaSO_4$ is filtered off. The filtrate containing the P_2O_5 is then condensed by evaporation and mixed with coarse wood charcoal; the mixture is dried, and finally strongly heated in retorts, when the P distills over and is condensed in H_2O. It is cast in moulds for market.

Uses and Test.

P is used chiefly in making friction matches. The wood for matches is cut into splints by machinery, the splints are dipped into melted S, paraffine, or stearine, and tipped with a composition consisting of P, a substance (generally saltpetre, manganese dioxide, or potassium chlorate) which readily gives up O, and glue or gum. *Safety matches* are tipped with a mixture of potassium chlorate and antimony sulphide; the composition contains no P. These matches are rubbed in lighting on a prepared surface composed of red P, manganese dioxide, and glue. Free P is detected by its faint luminosity.

Hydrogen Phosphide (PH_3).

PH_3 (phosphuretted hydrogen) is a colorless, offensive smelling gas, which possesses the property, under certain conditions, of inflaming spontaneously on coming in contact with air. It is produced naturally by the decay of animal matter. It is generally prepared by heating P with a strong solution of a caustic alkali, H_2O being decomposed.

To Prepare PH_3.—*App.*—Short-necked flask of about 200 c.c. capacity, with a long glass delivery tube, retort stand with wire gauze, and lamp. *Mat.*—40 g. of potassium or sodium hydrate ("Concentrated lye" used in making soap answers the purpose) dissolved in about 100 c.c. of H_2O, about 1 g. of P in several fragments, ether, and H_2O in water pan.

Exp. 142.—Support the flask on a ring of the stand and adjust the delivery tube so that its free end dips just below the surface of the H_2O in the pan; then put in the alkali solution, P, and a few drops of ether (the vapor of which expels the air from the flask), and heat. PH_3 forms (after heating for several minutes) and its bubbles, on coming into the air, burst into flame, forming, in still air, beautiful rings of smoke.

Phosphorus Oxides and Acids.

Phosphorus trioxide (P_2O_3, phosphorus anhydride) is a white, amorphous powder formed by the burning of P in a limited supply of air. **Phosphorus pentoxide** (P_2O_5, phosphoric anhydride) is a white, flocculent powder, with a strong affinity for H_2O. It is formed by the rapid burning of P in an excess of air or O.

To PREPARE P_2O_5.—*App.*—Wide-mouthed l. bottle, saucer (or plate), and small porcelain crucible. *Mat.*—½ g. P.

Exp. 143.—Dry the app. thoroughly, which may be done by leaving it supported for 15 or 20 minutes over a kerosene flame, then put the P in the crucible placed on the saucer, light it, and invert the bottle over it. The P_2O_5 collects on the sides of the bottle and in the dish. *Exp.* 144.—To show the affinity of P_2O_5 for H_2O, throw a little of it on H_2O. A hissing sound, like that produced by hot iron in H_2O, is heard.

There are several acids of P, three of which are formed by the union of P_2O_5 with H_2O; *ordinary phosphoric acid* (H_3PO_4) *pyro-phosphoric acid* ($H_4P_2O_7$) and *meta-phosphoric acid* (HPO_3).

ARSENIC (As) 75.

As is a steel-gray, brittle solid, with a metallic lustre and a crystalline structure. Heated to dull redness, it emits a garlic-like odor by which it is known. It forms with many metals alloys which it tends to render bright and brittle. Shot contains a little As, which is added to the melted lead to help it form into regular globules. As is very poisonous; it is the chief constituent of "fly poison."

As in small quantities, sometimes free, is widely distributed. Its most abundant compound is an ore composed of iron, S, and As. It is generally prepared from this ore.

Hydrogen Arsenide (AsH_3).

AsH_3 (arseniuretted hydrogen) is a colorless, offensive smelling, and intensely poisonous gas. It may be prepared mixed with H by putting a solution of As or of an As compound into a vessel in which H is generating from zinc (Zn) and dilute acid.

To PREPARE AsH_3.—*Marsh's Test.*—*App.*—Large test-tube with cork and jet-tube like that for burning H (Exp. 20), and the lid of a porcelain crucible (or a piece of a saucer or plate). *Mat.*—2 or 3 g. Zn, HCl, and an aqueous solution of white arsenic.

Exp. 145.—Generate H in the tube, light the jet when the air is expelled from the app., and hold the lid in the flame. No dark spots appear if the materials contain no As. Add a few drops of the As solution and relight the jet. Hold the lid again in the flame, which is now of a whitish color, and As is deposited on it, forming a black metallic spot. The forming of As spots in this way is *Marsh's Test.* By it exceedingly small quantities of As can be detected. Repeat the test, using a small piece of green wall or box paper, or scrapings of green paint instead of the As solution.

Arsenic Trioxide (As_2O_3).

As_2O_3 (arsenious oxide, acid or anhydride, white arsenic, arsenic) is a white solid usually in the form of a compact cake. It is only sparingly soluble in H_2O, but dissolves readily in hot HCl. When heated it volatilizes unchanged; if heated with carbon, it gives up its O, and metallic As is produced. It is intensely poisonous. Its best antidote is freshly precipitated ferric hydrate.

To VOLATILIZE AND CRYSTALLIZE As_2O_3.—*App.*—Piece of glass tubing 3 or 4 in. long, and lamp. *Mat.*—Piece of As_2O_3 as large as a pin's head.

Exp. 146.—Volatilize the As_2O_3 in the tube, first warming the tube beyond the As_2O_3. The substance crystallizes on cooling. Examine the crystals with a lens.

To PRODUCE As BY HEATING As_2O_3 WITH CHARCOAL.—*Reduction test.*—*App.*—Piece of glass tubing 3 or 4 in. long, drawn at one end and sealed as shown in Fig 20, lamp, and blow-pipe. *Mat.* Piece of As_2O_3 as large as a pin's head, and fragment of charcoal.

FIG. 20.—REDUCTION OF As_2O_3 BY CHARCOAL.

Exp. 147.—Put the As_2O_3 in the bottom of the tube, and the C just above it. Heat the C red-hot with a blow-pipe flame, then throw the flame on the As_2O_3. The As forms a metallic mirror on a cold part of the tube. This experiment illustrates a delicate method of detecting As.

As_2O_3 is obtained chiefly from Germany in the roasting of

arsenical nickel ores. The As of the ore combines with O from the air. It is used in making Paris green, opaque glass, in dyeing and calico printing, as a medicine, and for other purposes.

Arsenic sulphides are *realgar* (As_2S_2), a red solid found as a natural product, and *orpiment* (As_2S_3), a yellow solid found as a natural product and also precipitated by hydrogen sulphide from arsenical solutions. The former is used in making fireworks, and the latter as a paint.

ANTIMONY (Sb) 120.

Sb is a bluish-white brittle solid, with a metallic lustre and a plated crystalline structure. At red heat it burns, antimony trioxide (Sb_2O_3) being formed. It is a constituent of several useful alloys, as type-metal (Sb and lead) which it causes to expand on solidifying and completely fill the mould, and Britannia metal, pewter, etc., to which it contributes hardness.

Sb is often found alloyed with As, silver, and other metals. It also occurs in combination with S in the sulphides of other metals. Commercial Sb is obtained from the mineral stibnite (Sb_2S_3).

BURNING OF Sb.—*App.*—Blow-pipe, piece of charcoal containing a cavity and mortar. *Mat.*—Sb.

Exp. 148.—Powder a little Sb, put it into the cavity of the coal, and direct the blow-pipe flame downward upon it. It soon melts, forming a bright globule. Drop this on the table or floor, and it will break into numerous smaller globules, which scatter in all directions, marking their paths by a smoky ash formed by the burning of the metal.

BISMUTH (Bi) 210.

Bi is a grayish-white, hard, brittle metal which, when pure, crystallizes more readily than any other metal. It combines to form alloys which are remarkable for their easy fusibility. An alloy composed of 2 parts of Bi, 1 of lead, and 1 of tin, called "fusible metal," melts at about 94° C. Bi is usually found in the metallic state, but it sometimes occurs in combination with other metals, especially S.

The other elements of the N group are rare. *Vanadium* possesses the property of attacking vessels of glass and porcelain in which it is heated. The yellow oxide of *Uranium* is used for coloring glass, and the black oxide as a pigment for painting on porcelain. These elements occur chiefly in rare minerals. Uranium is always found in nature combined with O.

GOLD GROUP.

GOLD, BORON, THALLIUM.

GOLD (Au) 197.

Au is the only metal having a yellow color. It is very dense and almost as soft as lead. Sp. gr. 19.3. It is extremely ductile and the most malleable of the metals, the thinnest gold leaf being only $\frac{1}{10000}$ of a millimetre thick. It does not change in air at temperatures below its melting point, and is not soluble in any single acid. Its common solvent is *aqua regia* (p. 43). It is always alloyed for use, generally with copper or silver, as in the pure state it would be too soft. Au for jewelry, watches, and coins is alloyed with copper; our gold coins consist of 9 parts Au to 1 of copper.*

Exp. 149.—Find the sp. gr. of a gold ring, also of a gold coin.

Au is widely distributed in nature, but generally in very small quantities. The most valuable deposits are found in California, Colorado, Nevada, and Australia. It usually occurs in the metallic state, alloyed with silver. It is found most frequently in quartz rock, and in alluvial soil known as *placers*. Large lumps are sometimes found; a nugget from Australia weighed 184 lbs.

* Seven metals were known to the ancients; gold, silver, copper, tin, iron, lead, and mercury. Gold, occurring as it frequently does in the sands of rivers, was probably the first metal known to man. Representations of the washing and fusing of gold are found as early as 2500 B. C. on Egyptian tombs. The oldest coins in existence are the *electrum* staters of Lydia, which consist of 3 parts gold to 1 of silver. On account of its unchangeableness, gold was called by the ancients the king of metals.

Au in quartz is extracted by bringing the crushed ore in contact with mercury, with which the Au forms an amalgam, and then removing the mercury by distillation. Au in placers is collected by a process of washing by which the lighter portions of the deposits are carried off by the H_2O. The grains of the metal are separated by mechanical means and the finer portions by the amalgamation process. Hydraulic mining consists in washing down with H_2O under great pres-

FIG. 21.—HYDRAULIC MINING.

sure, immense beds of auriferous deposits into channels so constructed as to collect the heavier sediment containing the Au.

There are several compounds of gold, the most familiar of which is *auric chloride* ($AuCl_3$), formed by dissolving Au in aqua regia.

BORON (B) 11.

B has three allotropic forms. Crystallized B is almost as hard as diamond, and the crystals are very brilliant. B is always found in nature combined with O as a constituent of boric acid and the borates, the most important of which is *borax.*

Boric or Boracic Acid (H_3BO_3).

H_3BO_3 is a white, greasy-feeling, crystalline substance, readily soluble in warm H_2O and alcohol. The alcoholic solution burns with a green flame which is a test for the pres-

ence of B. H_3BO_3 is collected in large quantities from the hot vapors issuing from the soil in certain volcanic districts of Tuscany. It may be obtained from any borate by the addition of an acid.

To Obtain H_3BO_3 from Borax ($Na_2B_4O_7$).—*App.*—2 test-tubes, lamp, and app. for filtering. *Mat.*—2 g. borax, H_2O, and HCl.

Exp. 150.—Put the borax and about 10 c.c. of H_2O in one of the tubes, and heat until the borax dissolves. Filter, if the liquid is not clear, and add some HCl. Crystals of H_3BO_3 separate as the liquid cools. The HCl combines with the Na of the compound, forming NaCl and liberating the H_3BO_3.

Exp. 151.—Make the flame test for H_3BO_3 by shaking a little of the acid with alcohol, pouring the solution on a tin lid, or in a crucible, and lighting it. The flame is tinged green.

Thallium is a rare metal resembling lead. Its compounds resemble those of both potassium and silver; they color a flame green. Tl is found in some varieties of iron pyrites, and in certain mineral waters.

IRON GROUP.

IRON, MANGANESE, NICKEL, AND COBALT.

IRON (Fe) 56.

Properties and Varieties.

Pure Fe is a white, soft, very malleable, ductile metal. Ordinary Fe, which contains small quantities of carbon, silicon, sulphur, and phosphorus, has a grayish-white color, and is harder than the pure metal. Fe dissolves in dilute HCl and H_2SO_4, and forms two series of salts; *ferrous*, in which it acts as a dyad, and *ferric*, in which it acts as a hexad. It remains unchanged in dry air at ordinary temperatures, but rapidly oxidizes in moist air.*

* Iron was known at a very early date. According to the book of Genesis its discovery is attributed to Tubal Cain; pagan tradition assigns the discovery to Vulcan. The Lacedæmonians coined iron into money, and it was used in Homer's time for axes and other instruments. Aristotle (born B. C. 384) describes the manner in which the Chalybes produced iron, and also a process of making cast steel.

There are two varieties of Fe, *cast iron* and *wrought iron*, differing mainly by reason of the different amounts of carbon they contain. Cast iron contains from 2 to 6 per cent., and wrought iron less than ½ per cent.

Cast iron has a crystalline or granular structure, is hard and brittle. It has the property of expanding in cooling, and hence will exactly copy a mold. It differs greatly in quality, the hardest variety, which is white and crystalline, being known as *white iron*, and the softest, which is gray and granular, as *gray iron*.

Wrought iron has a fibrous structure, is soft, malleable, and very tenacious. It is prepared from cast iron by burning out carbon, silicon, and other substances. This is effected by a process called *puddling* in a reverberatory furnace, a furnace

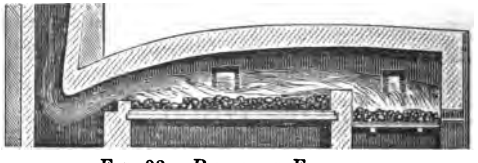

FIG. 22.—PUDDLING FURNACE.

so constructed that the substance is heated by the flame reflected upon it by the curved roof. The melted metal is constantly stirred to bring it in contact with air.

OCCURRENCE AND PREPARATION.

The free occurrence of Fe in nature, except in aerolites, is doubted, but its ores are very numerous and abundant, and it is a constituent of almost all natural substances. Its most valuable ores are the oxides and carbonates.

In extracting Fe from its common ores (oxides), H_2O, CO_2, etc., are first expelled from the ore by roasting; the O is removed by igniting with C, CO_2 being formed; and finally the earthy impurities are removed by the fusion of these with a flux which has been mixed with the ore, slag being formed.

The reduction is made in a tall furnace lined with fire-brick,

called a *blast furnace.* The furnace is open at the top and closed at the bottom, near which pipes enter to convey hot air,

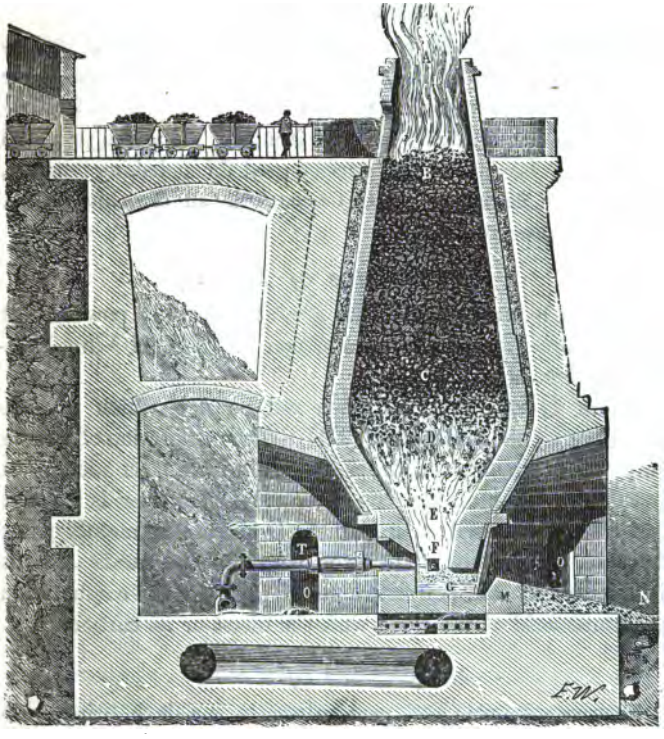

FIG. 23.—BLAST FURNACE.

which is forced in to support the combustion. The furnace is charged at the top, the fuel (charcoal, anthracite coal, or coke), the ore, and the flux (generally limestone), being placed in alternate layers. The melted Fe and slag flow out at the bottom into a dam; the slag flows off over the top, and the Fe is drawn off into channels made in sand. This product is *cast iron.*

The great variety of uses to which iron can be put, and

hence its close connection with the world's work, renders it the most useful of all metals.

Oxides of Iron.

Ferrous oxide (FeO) is a black powder about which little is known on account of its proneness to absorb O and form ferric oxide. **Ferric oxide** (Fe_2O_3, iron sesquioxide) is widely distributed as hematite and specular iron ore. It is also prepared for paint. *Rouge* is a fine variety used for polishing jewelry, glass, etc. **Magnetite** (Fe_3O_4) occurs as an ore, and is the richest of the iron ores.

Hydrates of Iron.

Ferrous hydrate (FeH_2O_2) is a white, unstable powder. It may be precipitated by the addition of $(NH_4)HO$ to a solution of ferrous sulphate.

Ferric hydrate ($Fe_2H_6O_6$), is a red powder, which may be produced by the addition of $(NH_4)HO$ to a solution of ferrous sulphate to which a few drops of HNO_3 have been added. It is valuable as an antidote for arsenic. *Yellow ochre* is a native ferric hydrate used as a paint. Iron rust is mainly ferric hydrate. The black stain formed around the heads of nails in unseasoned oak, is *iron tannate*, formed by the combination of tannic acid of the wood with the metal or its carbonate.

Sulphides of Iron.

Ferrous sulphide (FeS, protosulphide), is a dark, brittle substance, prepared by fusing Fe with S. It is used in preparing hydrogen sulphide. **Ferric disulphide** (FeS_2, iron pyrites) is an abundant ore occurring in cubical crystals. It is valueless for its iron, but is used as a source of S and in the manufacture of H_2SO.

Sulphates of Iron.

Ferrous sulphate ($FeSO_4$) is prepared by roasting Fe_2S gently, also by dissolving Fe or FeS in dilute H_2SO_4. Its solution produces crystals called *green vitriol* or *copperas* ($FeSO_4$

$+ 7\ H_2O$). These slowly effloresce in dry air, becoming covered with a white crust. Green vitriol is used extensively in dyeing and in making Prussian blue.

DYEING WITH GREEN VITRIOL.—*Mat.*—Piece of cotton cloth, solution of green vitriol, and solution of nut galls, prepared by boiling in a flask 5 g. of the powdered galls in 100 c.c. of H_2O for several hours, and filtering.

Exp. 152.—Dip the cloth into the galls solution, and when dry, dip it into the vitriol solution. It will be dyed black with the iron tannate formed.

Exp. 153.—Find the sp. gr. of Fe. *Exp.* 154.—Prepare FeH_2O_2, $Fe_2H_6O_6$ and $FeSO_4 + 7\ H_2O$. Notice how the precipitate of the first changes in standing, first to green and then to a reddish brown.

Steel.

Steel is a metal of great strength, intermediate between cast and wrought iron. It contains from .2 to 2 per cent. of carbon. It embraces several varieties, known as *Siemens steel, crucible steel, blister steel,* etc., according to the method of manufacture. The most valuable property of steel for cutting instruments, springs, etc., is that which enables the metal to vary its hardness. Heated to redness and plunged into cold H_2O, it becomes so hard that it will scratch glass; reheated to redness and cooled slowly, it acquires almost the softness of ordinary iron; and between these extremes any degree of hardness can be obtained. *Tempering* consists in reheating the hardened steel to a temperature below redness and gradually cooling it.

Steel is generally produced either by carbonizing wrought iron, called the *cementation* process, by decarbonizing cast iron, called the *Bessemer* process, or by melting scrap iron in a bath of cast iron by a gas flame, called the *Siemens-Martin* or *open-hearth* process.

By the cementation process, bars of wrought iron are converted into steel by imbedding them in charcoal in close boxes and heating them to redness for several days. The iron gradually takes up C.

By the Bessemer process, melted cast iron is poured into a

large covered crucible called a *converter*, which swings on pivots to render it easily emptied. A strong blast of compressed air is forced into the molten mass through holes in the bottom of the crucible, oxidizing the C and silicon and some Fe. This oxidation produces intense heat which keeps the iron melted. After the action has continued for several minutes, the air-current is stopped and a small quantity of *spiegeleisen* (a variety of pig iron containing manganese and C) is added, by means of which the iron is recarbonized or converted into steel. The melted metal is run into ingots.

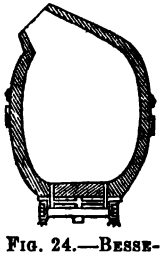

FIG. 24.—BESSEMER CONVERTER.

By the Siemens-Martin process, the scrap and cast iron are heated in a reverberatory furnace by a burning mixture of hydro-carbon gases and air, and the melted product is recarbonized by the addition of spiegeleisen, as in the Bessemer process.

MANGANESE (Mn) 55.

Mn is a grayish-white hard metal, which rapidly oxidizes in moist air. It does not occur free in nature. Its most common and valuable ore is the dioxide.

Compounds.

Manganese dioxide (MnO_2, black oxide of manganese) is used extensively as a source of O and Cl, and for coloring glass. **Potassium permanganate** ($K_2Mn_2O_8$) is a dark purple, crystalline salt. It readily gives up its O, and for this reason is used extensively as a disinfectant.

NICKEL (Ni), COBALT (Co).

Ni and Co are white metals very much alike. Ores of Ni occur in Lancaster County, Pa. (where the largest deposit known in the U. S. is found), New Caledonia, and other places. Co is found associated with Ni. Ni is an ingredient of German silver, and is much used for coating (nickel plating) iron

and steel. *Cobalt monoxide* (cobaltous oxide) is used to give a blue color to glass. A dilute solution of *cobaltous chloride* forms blue sympathetic ink.

Exp. 155.—Write on paper with an H_2O solution of cobaltous chloride so dilute that the characters cannot be seen, and warm the paper. The writing becomes blue. Breathe on the paper and the blue disappears. The color is due to the removal of H_2O from the chloride.

CHROMIUM GROUP.

CHROMIUM, MOLYBDENUM, TUNGSTEN.

CHROMIUM (Cr) 52.2.

Cr is a white metal, somewhat rare, and is not found free in nature. Its principal ore is chrome iron ($FeCr_2O_4$). The chromium compounds, many of which have bright colors, are used as paints, in dyeing, etc.

TO PREPARE CHROME ALUM.—*App.*—Small beaker, and evaporator. *Mat.*—5 g. potassium dichromate ($K_2Cr_2O_7$), and H_2O, H_2SO_4, and alcohol.

Exp. 156.—Dissolve by heating the $K_2Cr_2O_7$ in 30 c.c. of hot H_2O, and when the liquid is cool, add 5 c.c. of H_2SO_4; when the liquid is again cool add 3 c.c. of alcohol. Let the beaker stand for several hours, and its bottom will become covered with crystals of chrome alum. Potassium sulphate and chromium sulphate, which are formed, combine to form the alum. The alcohol becomes oxidized.

The other elements of the Cr group are rare. *Molybdenum* closely resembles graphite. It is remarkable for its numerous and very complex compounds. *Tungsten*, when alloyed with steel, renders that metal very hard. Sodium tungstate has been used to lessen the inflammability of dress goods, etc. These elements occur only in a few minerals. Mo is usually found in combination with S, and Wo with calcium.

PLATINUM GROUP.

PLATINUM, IRIDIUM, OSMIUM, PALLADIUM, RHODIUM, RUTHENIUM.

PLATINUM (Pt) 194.8.

Pt is a grayish-white, very heavy metal. Sp. gr. 21.5. It

is exceedingly malleable, and so ductile that it may be drawn into wire only $\frac{1}{1200}$ of a millimetre in diameter. It does not change in air, and is infusible at the temperature of the hottest blast furnace, but its alloys with zinc, lead, tin, silver, and other metals are easily fusible. It is not soluble in any single acid, but dissolves slowly in aqua regia. *Platinum black* and *platinum sponge* are preparations of the metal in a finely divided state.

Pt is found in the metallic state, and is generally alloyed with the other elements of its group, with copper, silver, etc. Its chief locality is the Ural mountains, but it is found also in California and other places. Pt is of great use to the chemist for crucibles and other apparatus, and is also used for the stills and siphons employed in the manufacture of H_2SO_4.

The other elements of the Pt group are much like Pt in color and hardness, and are all difficult to fuse. *Iridium* is the hardest known metal; most of its compounds are coloring agents. *Osmium* has never been fused. The most remarkable property of *Palladium* is its power to absorb or "occlude" H. In a finely-divided condition, it will absorb nearly 1000 times its volume of this gas. The sp. gr. of Ir is 21.15, and of Os 21.4. These elements are found in "platinum ores."

CARBON GROUP.

CARBON, SILICON, TIN, TITANIUM, ZIRCONIUM.

CARBON (C) 12.

C has three allotropic forms, *diamond*, *graphite*, and *amorphous carbon*.

Diamond.

Diamond is a (generally) colorless, brittle, crystalline solid, and the hardest known substance. Its great brilliancy is due to its power of dispersing and refracting light, and to its lustre. It resists the action of all known chemicals, and re-

mains unchanged by heat unless made red hot and put into O, when it burns with a brilliant light.*

The diamond is found in various places, the most extensive field being that of South Africa. It occurs as a semi-transparent pebble encased in a brownish crust. Its origin is unknown. Small diamonds have been produced artificially. The diamond is usefully employed in cutting glass, pointing drills for boring hard rocks, and for the jewels of watches.

Graphite.

Graphite (plumbago, black lead) is a dark, friable substance with a metallic lustre, and is either crystalline or amorphous. Like diamond, it does not fuse when subjected to the strongest heat, and burns in O. It generally contains some iron, but contains no *lead.*

Graphite is somewhat rare. Large deposits of it are found in Cumberland, Eng., at St. John, N. B., and in Siberia. It is probably of vegetable origin. Its principal use is for lead pencils (so called because the mark which they make on paper is similar to that made by lead). It is also used for crucibles in which to melt refractory substances, as gold and silver, for stove polish, and for diminishing the friction of machinery.

Amorphous Carbon.

Amorphous carbon includes *charcoal, animal charcoal, lamp-black,* etc., and *mineral coal.*

Charcoal.—Charcoal is a black, brittle, amorphous, very porous solid. It has the property, due mainly to its porosity,

* The diamond was first known to the Assyrians. It was first worn in the rough state and was thought to possess various medicinal virtues. The process of diamond cutting was discovered in 1476. The diamond was long regarded as a variety of silica, and its constitution was not correctly determined until the end of the 17th century. Two of the most celebrated diamonds in the world are the Koh-i-noor (mountain of light), weighing 123 carats and valued at about $10,000,000, belonging to Queen Victoria, and the Orloff, weighing 195 carats, belonging to the Russian crown. The largest diamond found in the U. S. was picked up near Richmond, Va., in 1856. Its weight was 23.7 carats. Diamonds that are colorless and perfectly transparent resemble a drop of clear water and are called diamonds of the "first water."

of absorbing gases in large quantities, of destroying odors, and of removing colors. It is insoluble in all liquids and only slightly fusible even in the intense heat of the voltaic arch. It combines with O with great energy at high temperatures, but at ordinary temperatures is one of the most unchangeable of substances.

POROSITY OF CHARCOAL.—*App.*—Lamp, blow-pipe, light iron wire, and piece of lead. *Mat.*—2 pieces of C, one of which is quite small, cold H_2O, and warm H_2O.

Exp. 157.—Heat the small piece of C, held by means of the wire, to redness, and continue heating for several minutes, then plunge it into the cold H_2O. It will sink because air has been expelled from its pores.

Exp. 158.—Attach the lead to the other piece of C and sink the C in the warm H_2O. Air will be driven from it and escape through the H_2O.

ODOR-DESTROYING PROPERTY OF CHARCOAL.—*App.*—Test-tube. *Mat.*—2 g. ferrous sulphide (FeS), 2 or 3 g. powdered C, and HCl.

Exp. 159.—Put the FeS in the tube and cover it with dilute HCl. H_2S, known by its smell, is produced. Put C in the tube, and the odor will disappear.

COLOR-DESTROYING PROPERTY OF CHARCOAL.—*App.*—Crucible, 2 funnels, etc., for filtering, retort stand, and lamp. *Mat.*—A small amount of the blue compound of iodine and starch (Exp. 61), a solution of blue litmus in H_2O and 5 g. bone ash (p. 95).

Exp. 160.—Heat the ash strongly in the crucible, then put it into the blue liquids, shake them well, and filter. Their colors will be destroyed. If the liquids do not come through colorless, pass them through again.

COMBINING OF CHARCOAL WITH O.—*App.*—Piece of glass tubing 3 or 4 in. long, sealed at one end, piece of C with a cavity, lamp, and blow-pipe. *Mat.*—1 g. copper monoxide (CuO), $\frac{1}{10}$ g. powdered C and $\frac{1}{2}$ g. litharge (PbO).

Exp. 161.—Mix the CuO and C and heat the mixture strongly in the tube. The C combines with the O of the CuO, forming CO_2, which escapes, and copper, known by its yellow color, remains.

Exp. 162.—Heat the PbO on the charcoal with a blow-pipe flame, and in a short time a globule of Pb will form. Explain.

Charcoal is generally prepared by burning large piles of wood, from which air is partly excluded by a covering consisting of moist earth, leaves, etc. The liquid and gaseous ingredients of the wood are thus expelled, and the solid portion remains. In countries where wood is scarce, charcoal is pre-

pared by heating the wood (also sawdust) in iron retorts; the volatile products are collected.

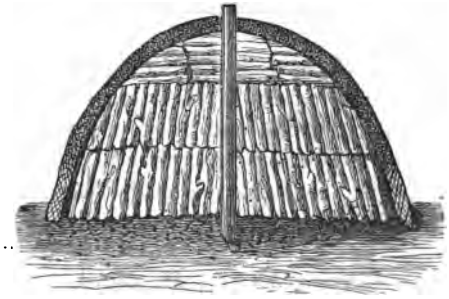

FIG. 25.—PREPARATION OF CHARCOAL.

TO SHOW THE PREPARATION OF CHARCOAL.—*App.*—Narrow glass tube sealed at one end, lamp, and pincettes. *Mat.*—Piece of match with the friction end removed.

Exp. 163.—Put the wood in the tube and, holding the tube with the opening inclined downward, heat it strongly until all the volatile products are expelled. The wood will be converted into charcoal. Remove the coal when the tube becomes cold, if necessary by breaking the tube, and hold it in an alcohol flame. It burns without smoke.

Charcoal is used as fuel in various metallurgical operations, and for reducing metals from their oxides in the smelting furnace. It is also used as a disinfectant. The lower ends of fence posts are sometimes charred to render them more durable.

Animal charcoal (bone black, or bone ash) is prepared by heating bones in iron retorts. It is used extensively in sugar refining and as an ingredient of shoe-blacking.

Lamp black is prepared by heating resin, pine knots, etc., and burning the disengaged vapors in a current of air not sufficient for their complete combustion. The familiar smoke on a lamp-chimney is lamp-black. The chief use of lamp-black is for black paint and printer's ink.

Coke is a porous solid obtained as a residue in the distillation of bituminous coal. It is a secondary product of the manufacture of illuminating gas. It is used extensively in the smelting of iron, for which it is prepared in large quantities.

Gas carbon is a very hard substance formed on the inner walls of the retorts in the manufacture of illuminating gas. It is used as an ingredient in carbon battery plates and carbon rods of electric lamps.

Mineral coal was formed by the slow decay of vegetable matter—moss, leaves, trunks of trees, etc.—without air and subjected to heat, moisture, and great pressure. *Anthracite coal* differs from *bituminous* in containing little of the H, O, and N of the original vegetable matter, having been subjected to a natural distillation.

Coal Gas (C, H, etc.)

Coal gas is a mixture of marsh gas (CH_4), olefiant gas (C_2H_4), H, and other gases. It is prepared by heating bituminous coal in large iron retorts, the gas being driven off with various other gaseous and liquid products. Coke remains in the retort.

The pipe conveying the expelled products from the retort dips into H_2O, which condenses aqueous vapor, tar, and salts of ammonium. The gas is then cooled and separated from the remaining tar, etc., by passing through iron pipes called *condensers*. It next passes through a tower filled with coke, over which H_2O trickles, to remove the remaining salts of ammonium, then over slacked lime to remove the hydrogen sulphide and CO_2, and finally enters the gas holder, from which it is forced to the burners. One pound of good coal yields about 5 cubic feet of the gas.

There are many *organic* substances composed of C and H, some of which will be treated under *Organic Chemistry*.

Carbon Monoxide (CO).

CO (carbonic oxide) is a colorless, odorless, poisonous gas. It burns with a blue flame, CO_2 being produced. In contact with heated metallic oxides it acts as a powerful reducing agent, combining with O with great energy. CO is a product of the combustion of anthracite coal, its burning producing

the blue flame often seen in coal stoves. It may be prepared by heating oxalic acid ($H_2C_2O_4$) with H_2SO_4.

To PREPARE CO.—*App.*—The apparatus used in preparing O (Exp. 63). *Mat.*—1 g. $H_2C_2O_4$ and H_2SO_4 and beaker of H_2O.

Exp. 164.—Arrange to collect the gas over H_2O, put the $H_2C_2O_4$ and sufficient H_2SO_4 to moisten it in the generator, and heat. Fill the receiver with the gas. *Exp.* 165.—To show the burning of the gas, cover the receiver and put it erect on the table. Then light the gas and quickly pour H_2O into the receiver to force the gas out.

Carbon Dioxide (CO_2).

PROPERTIES.

CO_2 (carbonic acid) is a colorless, slightly acid gas, 1.53 times as heavy as air. It is so heavy that it can be poured like H_2O. H_2O dissolves nearly its own volume of CO_2 at ordinary temperatures and pressures, and more than its volume when the gas is subjected to increased pressure and a lower temperature. H_2O, containing CO_2 under pressure, effervesces when the pressure is removed. CO_2 does not burn, extinguishes flame, and destroys life by suffocation.

OCCURRENCE AND PREPARATION.

CO_2 occurs uncombined in air. It is so heavy that it sometimes collects in wells and caves, rendering them dangerous to enter. It may be tested for in such places with a lighted candle, which it puts out, and may be removed by introducing dry slacked lime or freshly burned charcoal, which absorbs it. CO_2 is a constituent of all carbonates, forming nearly one-half of limestone, marble, etc., from which it can be removed by heat, as in "burning lime." It is one of the chief products of combustion, respiration, fermentation, and the decay of organic matter.

CO_2 A PRODUCT OF COMBUSTION.—*App.*—Candle or kerosene lamp and large test-tube. *Mat.*—Lime water (p. 76).

Exp. 166.—Hold the test-tube inverted for a few seconds over the flame, then remove it, covering it closely with a piece of wet paper, and, when sufficiently cool, pour in a little lime H_2O. Shake the tube

keeping it covered, and the liquid becomes milky white on account of the precipitate of calcium carbonate formed.

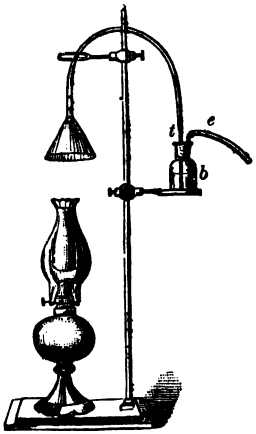

FIG. 26.—TO SHOW THAT CO_2 IS A PRODUCT OF COMBUSTION.

Fig. 26 represents an apparatus by which the result of Exp. 166 may be more beautifully shown. The tube *t* extends nearly to the bottom of the bottle *b*, and the tube *e* just through the cork. To use the apparatus, lime H_2O is put into the bottle, the lamp lighted, the free end of *e* connected with the upper bottle of the blower (p. 136) and the H_2O of the blower started. The products of the combustion are drawn through the lime H_2O. The operation may be performed slowly by suction with the mouth applied at the end of *e*.

CO_2 A PRODUCT OF RESPIRATION.—*App.*—Straight or bent glass tube about 1 ft. long. *Mat.*—Lime H_2O in a beaker (or other glass vessel).

Exp. 167.—Breathe through the tube into the lime H_2O. The presence of CO_2 is shown by the whitening of the liquid.

CO_2 A PRODUCT OF FERMENTATION.—*App.*—2 large test-tubes, porcelain mortar, and pine splinter. *Mat.*—Molasses, baker's yeast, lime H_2O, and H_2O.

Exp. 168.—Make a strong solution of molasses in H_2O, and add a little yeast, preparing liquid enough to fill one of the tubes and cover the bottom of the mortar to the depth of half an inch. Fill the tube, invert it in the mortar and put the app. in a warm place. Fermentation will soon begin, and the CO_2 given off will displace the liquid in the tube. When the tube is full of the gas, close it with a piece of paper and remove it. Test the gas with a flame, then pour it carefully (not allowing any liquid to accompany it) into the other tube, and test with lime H_2O.

FIG. 27.—TO SHOW THAT CO_2 IS A PRODUCT OF RESPIRATION.

CO_2 is generally prepared for experimental purposes from marble or chalk ($CaCO_3$) by means of HCl.

TO PREPARE CO_2.—*App.*—The generator used in preparing H, pneu-

matic trough, and 1 l. and 2 half-l. wide-mouthed bottles. *Mat.*—3 or 4 g. $CaCO_3$ in lumps (marble may be used), and HCl.

Exp. 169.—Arrange to collect the gas over H_2O. Put the $CaCO_3$ in the generator, cover it with H_2O and add HCl. CO_2 is rapidly produced. Fill all the bottles.

Reaction.—$CaCO_3 + 2\,HCl = CO_2 + H_2O + CaCl_2$ (calcium chloride).

Illustrations of Properties.

Heaviness of CO_2.—*App.*—The wire beam and paper vessel used in showing the lightness of H (p. 25) with the vessel balanced mouth upward. *Mat.*—Bottle of CO_2.

Exp. 170.—Pour the CO_2 into the paper vessel, and the beam will turn with the weight of the gas.

Dissolving of CO_2 in H_2O.—*Mat.*—Bottle of CO_2 and H_2O.

Exp. 171.—Put a little H_2O in the bottle of CO_2, close the bottle with the hand or a cork, and shake it. CO_2 is absorbed. Open the mouth of the bottle under H_2O, and more H_2O will enter. Then shake again and continue the operation until all the CO_2 is absorbed.

Exp. 172.—Mark the position of the H_2O in the mouth of one of the bottles of CO_2, and allow the bottle to remain inverted for several hours. The H_2O will absorb the gas and rise.

Extinguishing of Flame by CO_2.—*App.*—Lamp, tuft of cotton fastened to the end of a wire (or pine splinter), and tall beaker. *Mat.*—Bottle of CO_2, alcohol, and short candle.

Exp. 173.—Wet the cotton with alcohol and thrust it into the gas. The light goes out.

Exp. 174.—Light the candle, set it in the beaker, and pour the CO_2 upon it. The light goes out.

Fig. 28.—Pouring CO_2 on a Flame.

The effect of CO_2 on animal life is analogous to its effect on a flame. Since every respiration vitiates the air about us, it is highly important that the apartments in which we live be properly ventilated. The products of respiration and combustion *ascend;* hence to ventilate a room properly there should be an opening near the ceiling to allow the vitiated air to pass out, and another near the floor to admit pure air.

Uses and Tests.

CO_2 is sometimes used for extinguishing fires, and the effectiveness of "fire extinguishers" is due to this gas. "Soda water" is H_2O into which a large quantity of CO_2 has been forced. It contains *no sodium compound.* CO_2 is most easily detected by the lime-water test.

Combustion.

In *ordinary combustion* O from air combines with compounds of C and H to produce heat and light. The gaseous products are mainly H_2O vapor and CO_2.

In the burning of a candle, the tallow, reduced to an oil by the heat, is drawn up the wick into the flame, where it is converted into a gas. This gas forms the dark part of the flame, 1, (Fig. 29). O from the air combines with the H of the gaseous compound, producing an intense heat. The carbon particles, which are at the same time set free, are made white-hot by this heat, producing the luminous part of the flame, the cone, 2. The hot carbon particles move outward and combine with O in the transparent cone, 3, CO_2 being formed.

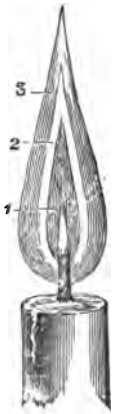

Fig. 29. — Parts of a Flame.

In the burning of an oil lamp, the combustible material, which in the burning candle is *reduced* to an oil by the heat of the flame, *is* an oil. The chimney, by confining the heated products of combustion, causes them to ascend more rapidly, and hence causes a larger quantity of O to be drawn into the flame, thereby increasing the energy of the combustion.

A lamp smokes when all the C of the burning material does not combine with O. *Flat* wicks are generally used because they present so large a surface to the air. The superior light afforded by the "student lamp" is due to a large surface of wick exposed to a current of air going to the interior of the flame, and to the peculiar form of the chimney, which deflects the ascending outer air current upon the flame.

In the burning of gas, the combustible material, which in the burning candle and lamp is *reduced* to the gaseous condition by the heat of the flame, *is* a gas.

To Show that the Dark Part of a Flame is a Combustible Gas, that the Luminous Part Contains C, and the Transparent Part CO_2. —*App.*—Glass tube 6 in. long and kerosene lamp without chimney (or candle).

Exp. 175.—Hold the tube in an inclined position with one end in the dark part of the flame. Gas will go up the tube. Light it.

Exp. 176.—Hold the end of the tube in the luminous part of the flame and smoke (the C cooled) will pass off through it.

Exp. 177.—Replace the funnel (Fig. 26) by a tube, and so adjust the apparatus that the end of the tube just reaches to the yellow part of the flame, then start the H_2O in the blower. The lime H_2O quickly whitens.

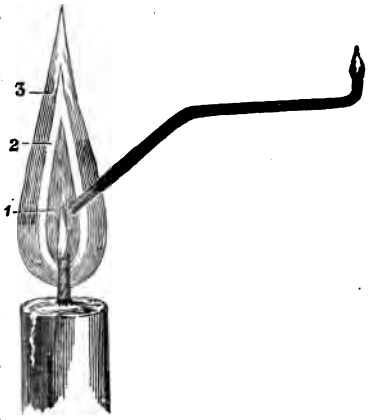

Fig. 30.—Gas from a Flame

To Show that the Luminosity of Flame is Due to Intense Heating of Carbon Particles.—*App.*—Alcohol lamp. *Mat.*—Finely powdered charcoal or iron filings.

Exp. 178.—Take the lamp lighted and the mat. into a dark room. The nearest objects can scarcely be seen, because, there being little C in alcohol, its flame is only slightly luminous. Sprinkle the powders into the flame, and it will become luminous.

Since the central part of flame is a gas not burning, the luminous part must be hollow.

To Show that the Luminous Part of Flame is Hollow.—*App.*—Piece of fine platinum wire 3 or 4 in. long, pine splinter, white paper, and lamp.

Exp. 179.—Hold the wire across the flame just above the end of the wick. Only the sections of wire in the outer shell of flame will become red hot. *Find where the flame is hottest* by raising and lowering the wire in it.

Exp. 180.—Hold the splinter across the flame just above the wick. Only the sections in the outer shell will be charred.

Exp. 181.—Quickly lower the paper held with its plane horizontal upon the flame until it nearly touches the wick, and almost immediately remove it. A ring marking a cross section of the luminous part will be charred in the paper.

The *safety lamp* is a lamp to use without danger in mines. It consists of an ordinary oil lamp enclosed in wire gauze.

PRINCIPLE OF SAFETY LAMP.—*App.*—Piece of fine wire gauze and lamp.

Exp. 182.—Lower the gauze into the flame. The flame will not pass through because its temperature is so much reduced by the gauze conducting away heat.

When a safety lamp is carried into a place containing fire-damp, the explosive mixture passes into the gauze cylinder and burns. The workman is thus warned of the danger.

OXIDIZING AND REDUCING FLAMES.

Two well defined sections of a flame, called the *oxidizing* and the *reducing* flame, are much more prominently developed by means of the blow-pipe (p. 135). The oxidizing flame

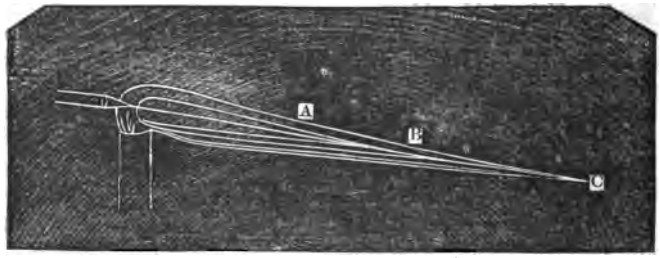

FIG. 31.—OXIDIZING AND REDUCING FLAMES.

(Fig. 31) is the yellowish outer cone *b c;* the reducing flame, the blue cone *a b*. These are so named from the fact that metals heated in the oxidizing flame combine with O, and metallic oxides heated in the reducing flame part with O. The greatest heat is at the point of the blue cone.

ACTION OF THE BLOW-PIPE FLAMES.—*App.*—Lamp, blow-pipe, and pincettes. *Mat.*—A copper cent.

Exp. 183.—Produce a blow-pipe flame and hold the cent in the oxidizing part. It becomes coated with copper oxide. Now hold it in the reducing part and its brightness is restored.

Carbon Disulphide (CS_2).

CS_2 is a colorless volatile liquid with an unpleasant odor. It has a very high refractive and dispersive power, and readily dissolves sulphur, phosphorus, fats, etc. It is prepared by passing S vapor over glowing coals.

Cyanogen (CN or Cy).

CN is a colorless, poisonous gas, analogous to Cl in many of its properties. It burns with a beautiful reddish flame. It is found in the gases of the blast furnace, and may be prepared by igniting the cyanides of certain metals. Compounds of CN with metals, etc., are called *cyanides.*

To Prepare CN from Mercury Cyanide ($HgCy_2$).—*App.*—Piece of glass tubing about 8 in. long, and lamp. *Mat.*—½ g. $HgCy_2$.

Exp. 184.—Seal the tube at one end by drawing off the end in the flame, put in the cyanide, and draw out the other end until the opening is quite small. Then hold the tube nearly horizontal with the sealed end in the flame, and CN will be given off. Light the gas as it escapes. Mercury will be found in the tube.

Reaction.—$HgCy_2 = Hg + 2\ Cy$.

Hydrocyanic acid (HCy, Prussic acid) is a colorless, poisonous liquid, which readily dissolves in H_2O and alcohol. It is so poisonous that one drop if swallowed will cause instant death. It is prepared by the action of an acid on a metallic cyanide. HCy combines to form *cyanides.*

SILICON (Si) 28.

Si has three allotropic forms, amorphous, graphite-like, and crystalline. It is next to O in abundance, forming about one-fourth by weight of the rocky crust of the earth. It is always found in nature combined with O, in quartz and silicates.

Silicon Dioxide (SiO_2).

The purest SiO_2 (silicic anhydride, silica) is *quartz,* a white, sometimes crystalline solid, next to diamond in hardness. It

is unaffected by the heat of the hottest blast furnace, but melts in the oxy-hydrogen flame; it is insoluble in H_2O, but dissolves in fluo-hydric acid and in sodium or potassium hydrate. Agate, amethyst, and other stones used in jewelry, are forms of silica. Silica is found in plants, especially in the stalks of grains and grasses.

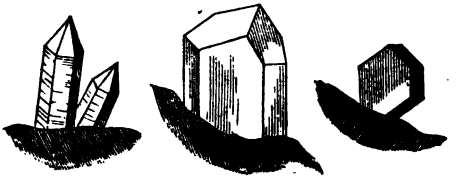

FIG. 32.—QUARTZ CRYSTALS.

Glass.

Glass is a mixture of potassium (K) or sodium (Na) silicate, or both, with another silicate or other silicates. *Window glass*, and *crown glass*, used for optical purposes, are silicates of Na and calcium (Ca). *Plate glass* is a silicate of Na or K, Ca, and aluminum (Al). Ordinary *bottle glass* is a silicate of Na, Ca, Al, and iron. *Bohemian glass*, used for chemical purposes, is a silicate of K and Ca. *Flint glass* is a silicate of K and lead. "*Crystal*," is a pure flint glass used for optical purposes and table ware. "*Strass*," the basis of artificial gems, is a flint glass with the proportion of lead increased. Soluble glass or water glass, is a silicate of K or Na or a mixture of them. It is a liquid soluble in H_2O.*

Glass is colored with certain metallic oxides, either by mixing them with the melted silicates, or by fusing them on the surface of the manufactured article. Thus, the oxides of iron give a dull green or brown, copper monoxide, ruby red, cobalt monoxide, a deep blue, and arsenious oxide, the dull white of lamp shades.

* It is not known which of the ancient nations discovered the process of making glass, but the oldest specimens are Egyptian, and representations of Egyptian glass-blowers on a tomb at Beni Hassan are supposed to date back to 3000 B. C. Glass coins were used in Egypt in the 11th and 12th centuries.

In making blown glass-ware the workman collects a mass of the hot glass on the end of his blow-pipe, an iron tube 5 or 6 feet long, and blows through the tube, while he at the same time rotates it and changes its position. *Window glass* is made by blowing a cylinder, cutting it, and opening it into a sheet. *Plate glass* is cast on a flat metal table, and after being annealed, is ground and polished. A large amount of glass-ware for household purposes is made in moulds. *Tubes* are made by drawing out hollow cylinders.

TIN (Sn) 118.

Sn is a silver-white, lustrous, very malleable metal with a crystalline structure. Sp. gr. 7.29. In bending a bar of the metal, the breaking of the crystals produces a peculiar sound, called the "cry of tin." Sn dissolves readily in HCl. It does not tarnish in air.

Sn is rarely found free in nature, and its ores occur only in a few localities. The principal source of the metal is the dioxide called *tin stone*, the richest mines of which are those of Cornwall, England, and Malacca, India. It is obtained from the ore by reduction with C.

The lustre of Sn and its unchangeableness in air render it valuable for coating other metals. *Tin-ware* is made of sheet-iron coated with tin. This tin-ware coating often contains lead, which may be a source of slow poisoning, since the acid of vinegar forms with lead poisonous lead acetate.

Ordinary pins are made of brass wire and brightened by a thin coating of Sn. Sn is a constituent of several useful alloys. Plumber's solder and pewter are composed of Sn and lead, bronze and bell-metal, of Sn and copper, and Britannia metal, of Sn, copper, and antimony.

Exp. 185.—To test for lead in tinned iron (tin), put a drop of strong acetic acid on the surface to be tested and add to it a drop of a solution of potassium iodide. If lead be present, there is formed in two or three minutes a yellowish spot of lead iodide. Or moisten the surface to be tested with H_2SO_4. If lead be present the moistened spot becomes brown.

Compounds.

Stannic oxide (SnO_2) and **stannous chloride** ($SnCl_2$, tin salt), prepared by dissolving Sn in HCl, are the most important compounds of the metal. $SnCl_2$ is much used in dyeing.

The other elements of the C group are rare. *Titanium* possesses the peculiar property of combining with N in several proportions. Its most abundant source is Titaniferous iron. *Zirconium* has the allotropic forms of silicon, which it closely resembles. It is found only in rare minerals.

PRACTICAL QUESTIONS.

1. Why is only a limited amount of air admitted to the wood in the preparation of charcoal?
2. Why does not an alcohol flame "smoke" a surface with which it comes in contact?
3. How much CO_2 would the burning of 1 gram of CO produce?
4. Name some natural carbonates. Some artificial. Some compounds that are not carbonates.
5. There are about 3 volumes of CO_2 in 10,000 volumes of air. Why does the amount vary?
6. How much heavier is limestone than lime?
7. How many grams of marble are required to produce 1 gallon of CO_2?
8. What is the blaze of a fire? Why do not fires always blaze?
9. What is the chemistry of smothering out a fire?
10. Why does a draft of air cause a fire to burn more brightly and a lamp to smoke?
11. Why is the heat of flames increased by the use of the blow-pipe or bellows? Would blowing the flame with the breath increase it?
12. Of what advantage are the tall chimneys of certain manufactories?
13. Why do shavings kindle more quickly than blocks?
14. Why is there a great waste of material in ordinary combustion?
15. Why will a match just kindled not light a lamp?

ORGANIC CHEMISTRY.

There is no essential distinction between inorganic and organic chemistry. The latter term is used simply for convenience in classification. It was introduced when it was supposed that the substances formed in animals and plants could not be produced without the intervention of life. Although multitudes of such substances are now produced artificially, yet since most of them are derived from organic substance, and since they possess characteristics of composition and structure not belonging to other classes of compounds, it is convenient to include them under the head of organic chemistry.

HYDROCARBONS AND DERIVATIVES.

The hydrocarbons are compounds consisting only of C and H. They are arranged in series, each term differing from the preceding by the quantity CH_2. Many of them are produced by the destructive distillation of wood, coal, and other organic substances. Only a few of them are discussed in this treatise. The most important series of hydrocarbons are the *paraffines* (or methanes), *olefines*, and *aromatic compounds;* the most important derivatives are the *camphors, resins, alcohols*, and *ethers.*

Paraffines (CH_4, C_2H_6, C_3H_8, etc).

General Formula, C_nH_{2n+2}.

METHANE (CH_4).

CH_4 (methyl hydride, marsh gas) is a colorless, very light, combustible gas. Its burning produces CO_2 and H_2O. It is a product of decomposing vegetable matter in the mud of stagnant waters, and is often disengaged in coal mines, where, mixed with air, it produces the dreaded *fire damp.* It may be prepared by heating a mixture of sodium acetate and sodium hydrate.

Burning of CH_4.—*App.*—Large glass jar.

Exp. 186.—Fill the jar with CH_4 at the nearest pond, and bring a lighted match to its mouth. The gas burns with a yellow flame. CH_4 thus collected contains some CO_2.

Chloroform, $CHCl_3$, which may be regarded as derived from methane, three atoms of H being replaced by three of Cl, is a colorless, heavy, volatile liquid, prepared by distilling a mixture of bleaching powder and dilute alcohol. It is used in medicine as an anæsthetic, and in the arts as a solvent for the alkaloids, rubber, resins, etc.

Petroleum.

Petroleum, which is a mixture of paraffines, is a greenish, oily, combustible liquid. It is a natural product, found in great abundance in Pennsylvania and various other parts of the world. It is supposed to have been formed either by the spontaneous distillation of organic matter contained in the rocks (sandstone) where it is found, or by the condensation by these rocks of gas originating in much deeper strata. It is generally obtained by boring wells through the rocks under which it lies.

Kerosene.—The term kerosene, originally used to designate an oily product obtained from the distillation of bituminous coal, etc., is now applied to refined petroleum. The refining of petroleum consists in first heating it by steam pipes passing through it, and then subjecting it to a gradually increasing higher temperature. The steam heating drives off a light gas which is used as fuel, and the subsequent heating furnishes the following products; 1st, *gasolene* (a very light liquid); 2d, *benzine;* and 3d, *burning oil* (kerosene), which forms from 70 to 72 per cent. of petroleum.

Paraffin.—Paraffin, which is also a mixture of paraffines, is a white waxy solid, easily melting, and only slightly affected by acids or alkalies. It is found in nature in coal beds, and in some varieties of petroleum from which the paraffin of commerce is generally prepared. *Cosmoline* contains a mixture of soft paraffines.

Olefines (C_2H_4, C_3H_6, C_4H_8, etc).

General Formula, C_nH_{2n}.

Ethylene (C_2H_4).

C_2H_4 (olefiant gas, so named because it forms an oily compound with Cl) is a colorless, very combustible gas, burning with a luminous flame. It is prepared from H_2SO_4 and alcohol.

To Prepare C_2H_4 and Show its Burning.—*App.*—A qr.-l. flask with cork and delivery tube, half-l. wide-mouthed bottle with cover, pneumatic trough, retort stand with gauze, and lamp. *Mat.*—Alcohol, H_2SO_4, H_2O in a beaker, and clean sand.

Exp. 187.—Arrange to collect the gas over H_2O, put 25 c.c. of alcohol, 100 c.c. of H_2SO_4, and some sand, to prevent frothing, in the flask, and heat. After the air is expelled from the apparatus, fill the bottle with the gas. *Exp.* 188.—Close the bottle with the cover, and put it erect on the table; then light the gas and slowly pour H_2O into the bottle to force it out.

Aromatic Compounds (C_6H_6, C_7H_8, C_8H_{10}, etc).

General Formula, C_nH_{2n-6}.

Benzene or Benzol (C_6H_6).

Benzene is a colorless, volatile liquid, producing a very combustible vapor. It is a valuable solvent, dissolving sulphur, caoutchouc, wax, and fatty substances. It is found in coal-tar, from which commercial benzene is obtained by distillation. *Benzine*, used for removing grease, is obtained as a secondary product in refining petroleum.

Nitro-benzene is a yellow, oily liquid, with the smell of bitter almonds, prepared by the action of strong HNO_3 on benzene.

Aniline (C_6H_7N) is a liquid of light yellow color, becoming brown by long exposure to air and light. It is generally prepared by distilling nitro-benzene with iron filings and acetic acid.

The *aniline colors*, which embrace all the common colors, are prepared by the action of various substances on aniline. These colors are very intense and beautiful. The *aniline dyes*

are obtained from a mixture of aniline and *toluidine*, a substance derived from coal tar.

Carbolic Acid.—Carbolic acid, or *phenol*, when pure is a colorless, crystalline solid, which will absorb moisture and form an oily liquid. It has the odor of creosote, which it closely resembles, and has the property of preserving organic matter from decay and preventing the spread of infectious diseases. It is prepared from coal tar by distillation, and is much used as an antiseptic.

Exp. 189.—Prepare $CHCl_3$, using distilling app. (p. 27) and 40 c.c. H_2O, 2 c.c. alcohol, and 10 g. bleaching powder. Distill until 2 c.c. have passed over. The $CHCl_3$ will be in the bottom of the receiver. *Exp.* 190.—Prepare nitro-benzene, heating 2 or 3 c.c. of HNO_3 with a few drops of benzene. *Exp.* 191.—Dissolve a crystal of aniline red in alcohol, and pour the solution into a large bottle of H_2O.

Essential Oils ($C_{10}H_{16}$).

The essential oils are oily, inflammable substances, nearly insoluble in H_2O, and differing from the fatty oils by reason of their volatility and odors. They are soluble in alcohol, the solutions forming *essences*. The oil of turpentine, of cloves, of lemon, and of juniper, are essential oils. These oils are obtained from plants, occurring generally in the roots, leaves, petals, or fruit. They are generally prepared by distilling the plant substance with H_2O, the oil passing over with the steam and separating from the condensed H_2O. *Oil of turpentine* readily dissolves fixed oils and resins, this property rendering it valuable in the preparation of paints and varnishes.

Dissolving of, and Solvent Action of Oil of Turpentine.—*App.*—2 test-tubes and lamp. *Mat.*—Oil of turpentine, alcohol, and a little shellac.

Exp. 192.—Put some of the oil and some alcohol in a tube and shake. The oil dissolves.

Exp. 193.—Put the shellac and some of the oil in a tube and heat. The shellac dissolves.

To Prepare Oil of Turpentine.—*App.*—Distilling app., etc. (p. 27). *Mat.*—4 or 5 g. *turpentine* (a resinous substance which exudes from pine trees) and H_2O.

Exp. 194.—Put the turpentine and some H_2O in the retort and heat. The oil forms a layer on the H_2O in the condenser.

To PREPARE OIL OF CLOVES.—*App.*—Distilling app., etc. *Mat.*—5 g. ground cloves.

Exp. 195.—Put the cloves and several times its bulk of H_2O in the retort and heat, continuing the distillation until half the liquid has passed over. The oil collects in drops in the bottom of the condenser; it separates more completely when the liquid stands for several hours. The condensed H_2O has the odor of the oil. "Perfumed waters," as rose water, and Florida water, are prepared in this way.

Camphors and Resins.

Common camphor ($C_{10}H_{16}O$) is a white, volatile, combustible solid, readily soluble in alcohol, the solution forming "spirits of camphor." It is obtained by distilling with H_2O the wood of the camphor tree, which is indigenous to China and Japan.

Resins are generally amorphous, brittle, combustible solids, soluble in alcohol, the solutions forming varnishes. They are obtained from viscid exudations from plants. **Common resin** is the residue in the preparation of oil of turpentine. Shellac, copal, and mastic are resins. **Gum resins** are milky juices of plants solidified by exposure to air, as assafœtida, gamboge, myrrh. **Balsams** are certain exudations from trees, consisting mainly of a mixture of resins and essential oils, as Canada balsam.

Caoutchouc and **Gutta Percha** are the hardened juices of several tropical trees. The former only is elastic. *Vulcanized rubber* is a combination of these products with S. *Hard rubber* (vulcanite, ebonite) is prepared by subjecting vulcanized rubber to heat and pressure. It is used for combs, buttons, and many other purposes.

There are two well known fossil resins, *amber* and *asphalt* (asphaltum, or mineral pitch). The former is found on the coast of the Baltic Sea, and the latter in the region of the Dead Sea and in many other places, having probably been formed from petroleum.

Alcohols.

The term alcohol is given to a class of compounds, the most important of which is common alcohol, the intoxicating constituent of various drinks. The alcohols are all composed of C, H, and O, and may be regarded as derived from the hydrocarbons by the replacement of one or more H atoms by the group OH.

Methyl alcohol (wood spirit,) which is much like common alcohol, is prepared by distilling wood. It is used extensively in the preparation of varnishes.

Ethyl alcohol ($(C_2H_5)HO$, common alcohol, spirits of wine) is a colorless, volatile, inflammable liquid. Sp. gr. 0.79. It boils at 78° C., and has rarely been frozen. *Proof spirit* contains 50.8 parts by weight of alcohol to 49.2 parts of H_2O. Alcohol is prepared by distilling wines and other fermented liquors; it is also obtained from Indian corn, molasses, and other substances. It is used in making tinctures, for preserving zoölogical specimens, for heating in the chemical laboratory, for dissolving resins, oils, etc., and for other purposes.

Ethers.

Ethers may be regarded as oxides of the alcohol radicals.

Ethyl oxide ($(C_2H_5)O$, common ether) is a colorless, light, very volatile liquid which gives off a heavy, combustible vapor, and boils at 35° C.

VOLATILITY AND COMBUSTIBILITY OF ETHER.—*App.*—Long narrow test-tube, mortar, and wide-mouthed bottle with cover. *Mat.*—Ether and warm and cold H_2O.

Exp. 196.—Nearly fill the test-tube with cold H_2O, and fill the remainder with ether. Put H_2O in the mortar and, closing the tube with the thumb, invert it in the mortar. The ether goes to the top. Now, pour hot H_2O on the tube, and the ether is converted into vapor; then pour on cold H_2O and the vapor condenses to a liquid.

Exp. 197.—Pour a little ether in the palm of the hand. The wet surface feels cold by the evaporation of the liquid.

Exp. 198.—Put a few drops of ether in the bottle, and allow the bottle to stand loosely covered for about a minute. Then bring a flame to its mouth. The ether vapor burns.

Sulphuric ether is prepared by heating alcohol with H_2SO_4, and *acetic ether* generally by distilling an acetate with H_2SO_4 and H_2O. Ether is much used in medicine as an anæsthetic.

To Produce Ether.—*App.*—2 test-tubes and lamp. *Mat.*—Alcohol, H_2SO_4, sodium acetate, and H_2O.

Exp. 199.—Put equal quantities of alcohol and H_2SO_4 in one tube, and a little sodium acetate, H_2O and H_2SO_4 in the other, and heat the tubes gently. The two ethers, recognized by their odors, will be produced.

Aldehydes and Acids.

The **Aldehydes** and some acids are formed by the oxidation of alcohols, the former with a much less amount of O than the latter. The aldehydes are somewhat like *acetic* aldehyde, commonly designated simply *aldehyde*, a pungent, volatile liquid prepared from common alcohol.

Chloral is a thin, colorless, oily liquid, which forms with a small quantity of H_2O a white, crystalline mass called *chloral hydrate*, much used in medicine to produce sleep. It is prepared by the action of chlorine on alcohol.

CARBHYDRATES.

The **Carbhydrates** contain H and O in the proportion in which these elements exist in H_2O. They are very similar in composition and are easily converted into one another. They are very widely distributed in the vegetable kingdom, and form the most valuable constituent of plant life. The most important carbhydrates are the *sugars*, *starch*, *cellulose*, and *gums*.

Sugars.

Sucrose.—Sucrose ($C_{12}H_{22}O_{11}$, cane sugar), the chief sugar of commerce, varies in color from white to dark brown, has a crystalline structure, and is very soluble in H_2O. *Rock candy* is one of its crystalline forms. *Barley sugar* is melted sucrose, and *caramel*, used for coloring soups, wines, etc., is sucrose heated until it becomes brown.*

* Sugar is not mentioned before the beginning of the Christian era. According to Pliny, it was used in his time as a medicine, and when it

Exp. 200.—Prepare rock candy, making a very strong solution of sugar. *Exp.* 201.—Prepare barley sugar, heating just sufficiently to melt the sugar; also caramel. Pour them on a piece of white paper to cool.

Sucrose occurs in many plants, but is manufactured chiefly from the juice of sugar-cane, beet-root, and sugar-maple. In extracting sugar from cane, the juice is pressed out of the canes by passing them between rollers. Milk of lime is added to the liquid to correct its acidity and combine with impurities; it is then concentrated by evaporation in open pans, and on cooling the sugar crystallizes. The mother liquor, which is *molasses*, is drawn off, and the crystalline product is *brown sugar*.

Crude sugar is refined by dissolving it in H_2O, filtering the solution through animal charcoal to remove impurities and coloring matters, evaporating the solution and crystallizing. The solution is evaporated in *vacuum pans* (vessels from which the air and steam are partly exhausted) in order to boil it rapidly at a low temperature. The crystalline mass is drained, either by rotating it rapidly in a horizontal cylinder of stout netting (centrifugal machine) to form granulated sugar, or in moulds to form loaf sugar. The mother liquor is molasses.

Glucose.—Glucose ($C_6H_{12}O_6$, dextrose, grape sugar) has generally a brownish-yellow color, and is much less soluble and much less sweet than cane sugar. It is found in grapes, figs, and many other fruits, and is prepared by the long continued boiling of starch with a dilute acid.

Amylose.—Amylose (starch sugar) is a mixture of dextrose, dextrine, and other products, and is prepared by boiling starch with dilute H_2SO_4. It is manufactured in immense quantities under the name of glucose from Indian corn. It is used in making alcohol, in adulterating table syrup and cane sugar, for candies and other purposes.

Exp. 202.—To detect amylose or glucose in cane sugar, put equal

came into use for other purposes it was long a luxury only of the rich. Sugar-cane, which is nowhere found wild, is probably a native of Bengal.

quantities of pure sugar and of the sugar to be tested in small beakers, and set the beakers in hot H_2O. If the suspected sugar contains amylose or glucose, it will melt much more quickly, and look much more like molasses, than the other; and when the syrups cool it will remain liquid, while the pure sugar will become solid.

Fermentation.

Fermentation is the decomposition of certain substances under the influence of H_2O, air, and warmth. It is caused by the action, not understood, of living germs, which are generally introduced in the form of yeast, a *ferment*, into the substance to hasten the decomposition. These germs exist in air, and under favorable conditions, fermentation takes place without the addition of a ferment.

There are two stages of ordinary fermentation, the *alcoholic* and the *acetic*. Alcoholic fermentation changes grape sugar into, mainly, CO_2 (Exp. 168) and alcohol.

To Show that Alcohol is a Product of Fermentation.—*App.*—Distilling app., etc (p. 27). *Mat.*—A fermented liquid prepared by sweetening H_2O with molasses, adding some yeast, and letting the liquid stand in a warm place until it ferments.

Exp. 203.—Put the liquid in the retort and heat with a low flame. Continue the distillation until one-third of the liquid has passed over. Re-distil the condensed liquid, which is a mixture of alcohol and H_2O, by supporting the retort in H_2O and heating the H_2O. The product now obtained contains sufficient alcohol to be detected by its taste and smell, and probably by its flame. Prove the presence of alcohol in a fermented liquor, as wine or cider.

Acetic fermentation, by the absorption of O from air, changes alcohol into acetic acid and H_2O. It is a continuation of the alcoholic, as in the changing of cider to vinegar.

Alcoholic Liquors.

Fermented Liquors.—**Wine** is the fermented juice of the grape. No ferment is added, the juice being simply exposed in vats to air. *Sweet wine* is produced by checking the fermentation, and *champagne*, by bottling the fermenting liquid, thus causing it to retain the CO_2.

Beer is a fermented infusion of malt. Malt, which is gen-

erally made from barley, is prepared by soaking the grain, putting it in a warm place to sprout, and drying the sprouted grain at a high temperature. The malt is crushed and heated with H_2O to about 77° C. for several hours, the clear liquid (wort) is then strained off and boiled with hops, then yeast is added, and it is placed in the fermenting vessels.

In sprouting, there is formed in the seed an active ferment called *diastase* which, in heating the malt with H_2O, converts the starch into sugar and dextrine. The hops give to beer its bitter taste. Fermented liquors contain from 1 to 25 per cent. of alcohol.

Distilled Liquors.—Distilled liquors are prepared by distilling certain fermented liquids. **Brandy** is made by distilling wine, **whiskey** by distilling a wort generally obtained from corn or rye. Distilled liquors contain from 40 to 50 per cent. of alcohol.

Starch.

Starch ($C_6H_{10}O_5$) is a white powder composed of round or oval microscopic grains. It is insoluble in H_2O, but when heated in H_2O to about 60° C. the grains swell and burst, forming the jelly-like substance used for laundry purposes. Starch is found in all plants, but is most abundant in grains. It is obtained by reducing the vegetable substance to a pulp and washing this on a sieve which allows the starch to pass through and retains the other ingredients. The test for starch is the formation of a blue compound with iodine (Exp. 61).

Dextrine is a light yellow, gummy substance, soluble in H_2O. It may be prepared by heating starch to about 160° C., or by boiling starch paste with H_2SO_4. It is the chief ingredient of the mucilage used on postage stamps.

Cellulose.

Cellulose ($C_6H_{10}O_5$) is a white, tough substance which constitutes the largest part of plants, forming the outer wall of the vegetable cell. It is variously modified in different varieties of wood, in pith, bark, and fruit. Cotton and linen are

almost pure cellulose. We use cellulose in the form of wood, thread, paper, etc., and its decomposition gives us illuminating gas, charcoal, oxalic acid, and other substances. *Parchment paper* is prepared by dipping unsized paper into strong H_2SO_4.

Gun-cotton (pyroxylene) closely resembles cotton-wool in appearance, but is very explosive and burns without smoke or residue. It is prepared by soaking cotton or other cellulose in a mixture of HNO_3 and H_2SO_4, and letting it dry. Part of the H of the cellulose is replaced by NO_2.

Celluloid is a hard, tough, elastic substance, prepared by mixing gum camphor with a pulp of gun-cotton and compressing the mixture at a high temperature. It is used for combs, knife-handles, and various other purposes.

Collodion is a colorless, syrupy liquid, prepared by dissolving gun-cotton in a mixture of alcohol and ether. When it is spread over a surface exposed to air, the solvent evaporates, leaving a thin, adhesive membrane. This property of collodion renders it valuable in photography.

Exp. 204.—Prepare dextrine by heating powdered starch, stirring it until it becomes light yellow. Add H_2O, which dissolves the dextrine, and filter. Add to the filtrate alcohol, which precipitates the dextrine. *Exp.* 205.—Prepare parchment paper, washing the paper thoroughly after it has been immersed in the acid. *Exp.* 206.—Ignite a tuft of gun-cotton.

Gums.

The **Gums** are vegetable masses which with H_2O form adhesive liquids. **Gum Arabic,** the best known of these substances, is produced by an acacia tree. Its solution is much used as an adhesive paste. **Gum tragacanth** differs from gum Arabic in merely becoming soft and gelatinous, not dissolving, in H_2O.

ACIDS.

The **Organic Acids,** a large number of which are known, generally occur combined, but are sometimes found in a free state. The most important organic acids are *acetic, oxalic, tartaric, citric, malic, tannic,* and *salicylic.*

Acetic Acid ($C_2H_4O_2$).

Acetic acid is the acid of vinegar, of which it forms from 2 to 4 per cent. At a temperature above 17° C. it is a colorless, intensely sour liquid; below this temperature it becomes a transparent solid, called *glacial* acetic acid. Acetic acid is prepared by the oxidation of dilute alcohol; also by the distillation of wood. The crude distillate is called *pyroligneous acid.* Compounds formed by the action of acetic acid on metals, etc., are called *acetates*, as lead acetate (sugar of lead), copper acetate (verdigris).

To Prepare Pyroligneous Acid.—*App.*—Dry test-tube and lamp. *Mat.*—2 or 3 pieces of matches.

Exp. 207.—Put the wood in the tube and hold this horizontally in the flame of the lamp. The watery liquid formed is the acid. Prove its acidity with litmus paper.

Vinegar.—Vinegar is made by the fermentation (acetic fermentation, p. 115) of malt, wine, cider, and other alcoholic liquids. The liquid is either stored in imperfectly closed vessels and slowly converted into vinegar, or subjected to the "quick vinegar process." This consists in causing the liquid to trickle through beech-wood shavings soaked in vinegar. The action is greatly hastened by this process by reason of the vast amount of air-surface to which the liquid is exposed, oxidation taking place very rapidly.

Oxalic Acid ($C_2H_2O_4$).

Oxalic acid is a white, crystalline, very poisonous substance, soluble in H_2O. It occurs in the juices of the sorrel, rhubarb, and other plants, sometimes free, but generally combined. It may be prepared by the action of HNO_3 on starch or sugar; it is produced commercially by heating sawdust with potassium or sodium hydrate. Important oxalates are potassium and calcium oxalates.

To Prepare Oxalic Acid.—*App.*—Test-tube and piece of clean window glass. *Mat.*—1 g. starch and HNO_3.

Exp. 208.—Put the starch in the tube, cover it with HNO_3 and heat. When fumes of NO_2 no longer pass off, pour some of the solution on the glass. Crystals of the acid will soon form.

Oxalic acid is much used in calico printing. It is frequently used to remove ink-stains and iron rust, a soluble oxalate of iron being formed. It is sometimes taken by mistake for Epsom salt; the antidote is a mixture of chalk or magnesia and H_2O.

Tartaric Acid ($C_4H_6O_6$).

Tartaric acid is a colorless, crystalline substance, soluble in H_2O. It occurs in the juices of many plants. The commercial acid is prepared from *argol*, a hydrogen potassium tartrate, which forms on the inside of casks in which wine is fermenting. *Cream of tartar* is purified argol. Tartaric acid is much used in dyeing and in medicine. *Tartar emetic* is an antimony potassium tartrate; *Rochelle salt*, a sodium potassium tartrate. *Rochelle powders* consist of cream of tartar in one paper and hydrogen sodium carbonate in the other.

Citric Acid, Malic Acid.

Citric acid occurs in the orange, lemon, currant, and other acid fruits. It is prepared in large quantities from the juice of lemons. Magnesium citrate is used in medicine.

Malic acid occurs in apples, pears, and many other fruits, also in tobacco leaves. It exists in rhubarb as potassium malate, crystals of which may be obtained by evaporating the juice of rhubarb stalks.

Tannic Acids, Salicylic Acid.

Tannic acids constitute the astringent principles of plants. They possess the important property of forming insoluble compounds with many organic substances, on which property their action in tanning depends. They occur in the bark and leaves of the oak and many other plants, also in various roots and seeds. *Gallo-tannic acid* is one of these acids obtained from gall-nuts.

Salicylic acid is a white crystalline substance, somewhat soluble in H_2O. It occurs in the bark of the willow and in oil of wintergreen. It is prepared by passing CO_2 through a heated

mixture of pure carbolic acid and sodium hydrate and acidifying the residue (sodium salicylate). It is very valuable as an antiferment and disinfectant, and is used extensively in medicine.

ALKALOIDS.

The **Alkaloids** or *organic bases*, are bases of salts existing in plants, and embrace the plant poisons and medicinal principles. They all contain N, have a bitter taste, and are alkaline. They are only slightly soluble in H_2O, but dissolve in alcohol and produce soluble salts with acids. The most important alkaloids are *morphine, strychnine, nicotine, caffeine,* and *quinine.*

Morphine is one of the many alkaloids of opium, the dried juice of the poppy. It is very valuable in medicine as a sedative.

Strychnine is an extremely poisonous substance obtained from the St. Ignatius bean and nux vomica, seeds of East India plants. It is used in medicine.

Nicotine is the alkaloid of tobacco, the narcotic effects of which it produces. **Caffeine** (or theine) exists in tea and coffee. It forms about one per cent. of coffee.

Quinine occurs with cinchonine in cinchona or Peruvian bark, from which it is extracted as a sulphate. The sulphate and hydrochloride are much used in medicine.

ALBUMINOIDS.

The **Albuminoids** all contain C, H, N, O, and S, but they are very complex, and their chemical relations are imperfectly understood. They constitute only a small portion of plants, but the chief portion of animals. They are, however, formed in the plant, and introduced into the animal as a part of its food. The most important albuminoids are *albumen, fibrin, casein,* and *gelatin.*

Albumen is familiar as the white of eggs, of which it forms a large per cent. It is soluble in cold H_2O, and is coagulated by heat (as seen in cooking an egg) and other agents. It

occurs abundantly in the serum of blood and much other animal substance. *Vegetable* albumen is a similar substance existing in vegetables.

Fibrin forms a part of lean meat, from which it may be obtained by washing out the coloring matter. It is found in blood, forming the clot when blood coagulates. *Vegetable* fibrin is a similar substance found in *gluten*, the tough ingredient of dough.

Casein is familiar as the curd of milk, of which it forms a large part. It is coagulated by acids and by rennet, the fourth stomach of the calf, and differs from albumen in not being coagulated by heat. *Cheese* is made by warming milk with rennet and pressing the curd that forms. The thin liquid remaining after the curd is formed is called *whey*. *Legumin* is a substance like casein, found in almonds, peas, beans, and many other seeds.

Gelatin is a transparent, tough substance, soluble in warm H_2O, the solution forming a jelly on cooling. It is obtained by boiling bones, tendons, and other animal substances in H_2O. *Isinglass* is a pure gelatin made from the air-bladders of fishes. *Glue* is an impure variety, made chiefly from the refuse of hides.

Pepsin is a constituent of gastric juice, and is the active agent in digestion. It is artificially prepared by the action of HCl on the mucous membrane of the stomach (usually of the pig).

FATS AND FIXED OILS.

The **Fats** (which become oils when warmed) and fixed oils are mixtures chiefly of *stearin*, *palmatin*, and *olein*, which are salts of glycerine and stearic, palmetic, and oleic acids. Stearin is the chief ingredient of tallow, palmatin, of palm oil, and olein, of olive oil. The fats and fixed oils are not volatile, and permanently stain paper and wood, leaving a "grease spot." They are insoluble in H_2O, but soluble in ether and some other liquids. Some of them change when exposed to

air, undergoing a kind of fermentation and becoming "rancid." They are obtained from both animal and vegetable substances. Common fats are *butter*, *tallow*, and *lard*. Common oils are *linseed oil*, *olive oil*, and *castor oil*.

Butter consists of the glycerides of butyric and other acids, and is obtained from cream by breaking its oily globules by churning, and causing them to collect in a mass.

Linseed oil, called a *drying* oil, on account of its solidifying when exposed to air from the absorption of O, is obtained from flax seed. It is highly valuable as an ingredient of paints and varnishes. The tendency of the oil to dry is greatly increased by heating it with litharge. Thus prepared, it is called *boiled oil*. *Printer's ink* is a mixture of lampblack and linseed oil, heated until it becomes thick. *Olive oil* (sweet oil) is obtained from the fruit of the olive; *castor oil*, from the castor bean; *croton oil*, from an East India plant; *cod-liver oil*, from the liver of the cod-fish, and *sperm oil*, from spermaceti found in the brain of the sperm whale.

Glycerine.—Glycerine is a sweet, colorless syrup, soluble in H_2O, and itself an energetic solvent. It is prepared by decomposing fats with strongly heated steam, and is much used in medicine for external applications. Honey is frequently adulterated with it. *Nitro-glycerine* is an oily, very explosive liquid, prepared by allowing glycerine to run into a cooled mixture of strong HNO_3 and H_2SO_4. *Dynamite* is a mixture of nitro-glycerine and a porous substance, as silicious earth.

Soap.—Soap is formed by the union of an alkali, generally potassium or sodium hydrate, with the acid, generally oleic or stearic, of a fat or an oil. The alkali of hard soap is sodium hydrate, that of soft soap, potassium hydrate. Olive oil is used for castile soap. Soap aids in cleansing by its alkali combining with the oily matter (not soluble in H_2O) which the soiled article contains, to form another soap, soluble in H_2O.

COLORING SUBSTANCES.

The organic coloring substances of vegetable origin do not generally exist in a free state in the plant, but are in combination, and are set free by fermentation and by the action of acids and alkalies. They may occur in almost any part of the plant, and also in the seed. Many of them have been prepared artificially. The most important of these substances are *indigo*, *madder*, *logwood*, and *litmus*.

Indigo is a blue substance, composed of the coloring matter, *indigo blue*, and various impurities. Indigo blue is insoluble in H_2O, but dissolves in strong H_2SO_4, forming a deep blue solution. Indigo is obtained from several species of tropical plants. It is much used in dyeing and in making washers' blueing.

Madder is a reddish powder which yields *alizarin* and other important coloring matters. It is prepared from the roots of a plant cultivated in various localities in the East, and in other places. It is a dye of great value, producing all shades of red, purple, brown, and even black.

Brazil-wood, logwood, and **cochineal** (a dried insect containing the coloring matter *carmine*) are other red dyes.

Litmus, which is used by the dyer as a red coloring matter, is obtained from various European lichens. *Fustic,* a West Indian wood, and *turmeric,* an East Indian root, are common yellow dyes.

Dyeing.

To produce a *fast* color, or one that will not wash out, the coloring matter must combine with the fibres of the material. Only a few colors, as indigo, will do this; hence a third substance called a *mordant,* which has the property of fixing itself to the fibre and then uniting chemically with the dye, is generally used. Alum, ferrous sulphate, and salts of tin, are common mordants.*

* The most celebrated dye of antiquity was Tyrian purple, discovered as early as 1500 B. C. It was found in certain shell-fish of the Mediterranean. Each fish producing only a few drops, however, it was very dear, and was monopolized by royal families.

ACTION OF A MORDANT.—*App.*—Small beaker, retort stand, with gauze and lamp. *Mat.*—Solution of logwood prepared by dissolving 1 g. extract of logwood in 75 c.c. of H_2O, strong solution of alum, $(NH_4)HO$, and piece of cotton cloth.

Exp. 209.—Boil a piece of the cloth in half the logwood solution for several minutes, then wash it. Most of the dye will wash out. Now soak a piece of the cloth first in the solution of alum, then in the $(NH_4)HO$, and boil it in the remainder of the logwood solution. The color of this piece will not wash out.

QUESTIONS.

[FIGURES REFER TO PAGES.]

INTRODUCTION.

7. Give historical sketch. 8. Define matter. Atom. Molecule. Mass. What is the *atomic theory?* Define and give examples of substance. Organic substance. Inorganic substance. Physical properties of matter. Chemical properties. Define Chemistry. 9. Define and give examples of a chemical element. A chemical compound. How are compounds classified? What is an acid? A base? A salt? A radical? A simple radical? A compound radical? Define chemical analysis. Ultimate analysis. Proximate analysis. Synthesis. What is a mixture? How does it differ from a compound? Illustrate. 10, 11. What are the atomic weights of C, Cl, Au, H, Fe, N, O, K, Ag, Na, S, Zn? When and by whom was Cl discovered? H? N? O? P? K? Na? Give symbols of the common acids. 12. Define chemical affinity. Chemical action.

12. How are symbols used in chemistry? How are the elements named? How symbolized? How are general compounds named? How symbolized? 13. Explain the use of figures used with symbols. How are equations used to express chemical reactions? Define the term formula. Rational formula. Empirical formula. Illustrate. Explain and illustrate the naming of binaries. 14. Of ternaries. Define and explain the use of bond symbols. Of graphic symbols. State the law of definite proportions. Illustrate. 15. What are the atomic weights? Molecular weights? How is the percentage composition of a compound found? State the law of multiple proportions. Illustrate. Explain quantivalence. 16. What is meant by the terms, monad, dyad, triad, etc.? Give Ampere's law. Illustrate. 17. Give the law of volumes. Explain and illustrate. What is the product volume? The unit volume?

17. Define and illustrate the term hydrate. Alkali. Amorphism. 18. Allotropism. Isomerism. Catalysis. Nascent state. Water of crystallization. Mother liquor. Effervescence. Deliquescence. 19. Efflorescence. What is a reaction? A reagent? An alloy? An amalgam? Define solution. What is a solvent? How is solution shown? How may solution be hastened? 20. How is the hastening of solution

shown? What is a saturated solution? How is it made? Define crystallization. How is it shown? Why may crystals be produced by evaporation? How may their production in this way be shown? 21. Define precipitation. What is a precipitate? How is precipitation shown? Define filtration. How is it shown? Define distillation. 22. Destructive distillation. How are substances heated on charcoal? Define specific gravity. How is the sp. gr. of a solid found? How shown? How is the sp. gr. of a liquid found?

INORGANIC CHEMISTRY.

HYDROGEN. 23. Symbol. Atomic weight. Properties. Occurrence. Preparation. 24. Write and explain the equation expressing the reaction. How is the lightness of H shown? 25. The diffusibility? The H flame? The singing flame? 26. The formation of H_2O by burning H? What precaution should be taken in making experiments which require H to be lighted? How is it shown that H does not support combustion? Uses and tests. *Water.* Symbol. Properties. Occurrence. Composition. 27. What are the impurities of H_2O? How is it purified? Describe the process of distillation. 28. How is the purity of distilled H_2O proved? *Hydrogen dioxide.*

Sodium Group.—Name the elements of this group and give their common characteristics.

SODIUM. 29. Symbol. Atomic weight. Properties. How is the decomposing of H_2O by Na shown? 30. Occurrence and preparation. *Sodium hydrate. Sodium chloride.* Symbol. Properties. How may crystals of NaCl be prepared? Occurrence. 31. Preparation. Uses. What reason is there for believing that NaCl is a necessary article of food? *Sodium sulphate. Sodium carbonate.* Symbol, etc. 32. Describe Leblanc's process. What circumstance led to its discovery? *Hydrogen sodium carbonate. Sodium nitrate. Sodium biborate.*

POTASSIUM. 33. Symbol. Atomic weight. Properties. How is the decomposing of H_2O by K shown? Occurrence and preparation. *Potassium hydrate. Chloride. Bromide.* 34. *Cyanide. Potassium carbonate.* Symbol, etc. How is K_2CO_3 obtained from wood ashes? *Hydrogen potassium carbonate. Potassium nitrate.* Symbol, etc. How is KNO_3 shown to be an oxidizing agent? *Potassium chlorate.* 35. How is $KClO_3$ shown to be an oxidizing agent? Tests for Na and K. *Lithium* and its compounds. 36. SILVER. Symbol. Atomic weight. Properties. Occurrence. Preparation. Give facts relating to the early use of silver. *Silver chloride.* 37. *Silver nitrate.* Tests.

Chlorine Group.—Name the elements of this group and give their common characteristics.

CHLORINE. 38. Symbol. Atomic weight. Properties. Occurrence. Preparation. 39. Write and explain the equation expressing the reaction. How is the combining of Cl and H shown? The dissolving of Cl in H_2O? 40. The burning of oil of turpentine in Cl? The burning of antimony in Cl? Cl as a bleaching agent? 41. What is the action of Cl in bleaching? How is it shown that dry Cl will not bleach? Uses and tests. *Hydrochloric acid.* Symbol. Properties. Occurrence. 42. Preparation. Write and explain the equation expressing the reaction. How is the dissolving of HCl in H_2O shown? HCl as a solvent? Uses and tests. 43. *Aqua regia.* FLUORINE. Symbol, etc. How is etching with F shown? 44. BROMINE. Symbol, etc. How is Br prepared from potassium bromide? IODINE. Symbol, etc. 45. How is its vapor shown? Its dissolving in alcohol? Occurrence. Preparation. Uses and test.

Oxygen Group.—Name the elements of this group and give their common characteristics.

OXYGEN. 46. Symbol. Atomic weight. Properties. What are oxides? Occurrence. Preparation. 47. Write and explain the equation expressing the reaction. How does the MnO_2 act in this process? How are the MnO_2 and KCl separated? How is the producing of flame in O shown? The burning of charcoal? The burning of sulphur? The burning of phosphorus? What care should be taken in using P? 48. How is the burning of iron wire in O shown? The effect of O forced into a flame? Uses. Tests. 49. *Ozone.* Properties, etc. How is it prepared from P? Test. 50. *Combining of oxygen and hydrogen.* The OH flame. The OH blow-pipe. How is a mixture of O and H exploded?

SULPHUR. 51. Symbol. Atomic weight. Properties. What are sulphides. How is the crystallization of S shown? The preparation of plastic S? The dissolving of S? 52. Occurrence. Preparation. Uses. Tests. *Hydrogen sulphide.* Symbol. Properties. Occurrence. 53. Preparation. Write and explain the equation expressing the reaction. How is the dissolving of H_2S in H_2O shown? The burning of H_2S? Uses and tests. *Sulphur dioxide.* Symbol, etc. 54. How is the extinguishing of flame by SO_2 shown? Bleaching with SO_2? Uses and test. *Sulphur trioxide.* 55. *Sulphuric acid.* Symbol. Properties. What are sulphates? Give facts relating to the early production of the common acids. How is the corrosiveness of H_2SO_4 shown? The acidity? How is it shown that heat is produced by the combining of H_2SO_4 and H_2O? That H_2SO_4 contains lead sulphate? 56. Occurrence. Preparation. Explain the reaction. 57. Uses. Tests.

Calcium Group.—Name the elements of this group. What are the alkaline earths?

CALCIUM. 58. Symbol, etc. *Calcium oxide.* Symbol, etc. How is the slacking of CaO shown? 59. *Calcium hydrate.* Symbol, etc. What is the difference between lime-water and whitewash? What is bleaching powder? *Calcium chloride. Calcium carbonate.* 60. *Calcium sulphate. Calcium phosphate.* BARIUM and STRONTIUM. Symbols, etc. How is green fire made? 61. Red fire? LEAD. Symbol, etc. What danger is there in using water conveyed by lead pipes? *Compounds.* 62. Tests.

Magnesium Group.—Name the elements of this group and give their common characteristics.

MAGNESIUM. 62. Symbol, etc. How is the Mg light shown? *Compounds.* 63. ZINC. Symbol, etc. How is the lead tree made? 64. *Compounds. Cadmium.*

Aluminum Group.—Name the elements of this group.

ALUMINUM. 64. Symbol, etc. *Aluminum oxide.* Symbol, etc. 65. How is logwood lake prepared? *Aluminum sulphate.* Alum. *Aluminum silicate.* Symbol, etc. How are bricks, earthenware, and common pottery made? What is porcelain. How are these wares glazed? 66. *Indium, Gallium, Glucinum.*

Copper Group.—Name the elements of this group.

COPPER. 66. Symbol, etc. What reason have we for believing that copper was known at a very remote period? 67. *Oxides of copper.* Symbols, etc. How are Cu_2O and CuO formed? *Copper sulphate.* Symbol, etc. How is it shown that the color of blue vitriol is due to H_2O? *Copper acetate.* Tests. MERCURY. 68. Symbol, etc. What mines supply the largest amount of Hg? *Compounds.* Symbols, etc. By what simple test can calomel be distinguished from corrosive sublimate? 69. Tests.

Nitrogen Group.—Name the elements of this group and give their common characteristics.

NITROGEN. 69. Symbol. Atomic weight. Properties. Occurrence. Preparation. 70. How is it shown that N extinguishes flame? Uses and test. *Ammonia. Ammonium.* Symbol. Properties. 71. How is the dissolving of NH_3 in H_2O shown? The neutralization of an acid by NH_3? Occurrence. Preparation. 72. Write and explain the equation expressing the reaction. Uses. *Ammonium chloride.* Symbol, etc. How is the production of NH_4Cl fumes shown? *Ammonium carbonate. Ammonium nitrate.* 73. Tests. *Nitrogen monoxide.* Symbol, etc. 74. Write and explain the equation expressing the reaction which takes place in its preparation. *Nitrogen dioxide.* Symbol, etc. How is its affinity for O shown? *Nitrogen tetroxide. Nitric acid.* Symbol. Properties. How is HNO_3 as a solvent shown? 75. Occurrence. Preparation. Write and explain the equation expressing the reaction. Uses. How is

etching done with HNO_3? Tests. 76. *Air.* Properties. Composition. How is air analyzed? How is it shown that air contains CO_2? 77. Permanence and purity of the air.

PHOSPHORUS. 77. Symbol. Atomic weight. Properties. 78. How is the solubility of P shown? The inflammability? Red phosphorus. Luminous paint. Occurrence. Preparation. 79. Uses and Test. *Hydrogen phosphide.* 80. *Phosphorus oxides and acids.* ARSENIC. Symbol, etc. *Hydrogen arsenide.* Symbol, etc. 81. What is Marsh's Test? *Arsenic trioxide.* Symbol, etc. How are the volatilizing and crystallizing of As_2O_3 shown? How is As produced from As_2O_3? 82. *Arsenic sulphides.* ANTIMONY. Symbol, etc. How is the burning of Sb shown? BISMUTH. 83. *Vanadium. Uranium.*

Gold Group.—Name the elements of this group.

GOLD. 83. Symbol, etc. Why was gold probably the first metal known to man? Why was it called the king of metals? 84. What is hydraulic mining? *Auric chloride.* BORON. Symbol, etc. *Boric acid.* Symbol, etc. 85. How is H_3BO_3 obtained from borax? How is the flame test for H_3BO_3 made? *Thallium.*

Iron Group.—Name the elements of this group.

IRON. 85. Symbol. Atomic weight. Properties. What evidences are there that Fe was known at a very early date? 86. Varieties. What is puddling? Occurrence. Preparation. 87. Uses. 88. *Oxides of iron. Hydrates. Sulphides. Sulphates.* 89. How is dyeing with green vitriol shown? *Steel.* Varieties. Properties. Tempering. Preparation. 90. MANGANESE. NICKEL. COBALT.

Chromium Group.—Name the elements in this group.

CHROMIUM. 91. Symbol, etc. How is chrome alum prepared? *Molybdenum. Tungsten.*

Platinum Group.—Name the elements of this group.

PLATINUM. 91. Symbol, etc. 92. What are platinum black and platinum sponge? *Indium. Osmium. Palladium.*

Carbon Group.—Name the elements of this group.

CARBON. 92. Symbol. Atomic weight. *Diamond.* Properties, etc. 93. Give historical facts relating to the diamond. Large diamonds. *Graphite. Charcoal.* Properties. 94. How is the porosity of charcoal shown? Its property of destroying odors? Of destroying colors? The combining of C with O? 95. Preparation. Uses. Animal charcoal. Lamp black. Coke. 96. Gas carbon. Mineral coal. *Coal gas. Carbon monoxide.* 97. *Carbon dioxide.* Symbol. Atomic weight. Properties. Occurrence. How is it shown that CO_2 is a product of combustion? 98. Of respiration? Of fermentation? Preparation. 99. Write and explain the equation expressing the reaction. How is the heaviness

of CO_2 shown? The dissolving of CO_2 in H_2O? The extinguishing of flame by CO_2? Explain the effect of CO_2 on animal life. How should a room be ventilated? 100. Uses and tests.

Combustion. What is the action of O in ordinary combustion? Explain the burning of a candle. The burning of an oil lamp? When does a lamp smoke? Why are flat wicks generally used? To what is the superior light of the student lamp due? 101. Explain the burning of gas. How is it shown that the dark part of a flame is a combustible gas? That the luminous part contains C? The transparent part, CO_2? That the luminosity of flame is due to the intense heating of carbon particles? That the luminous part of flame is hollow? 102. What is the safety lamp? How is the principle of its action shown? What is the oxidizing flame? The reducing flame? Why are these flames so named? How is their action shown? 103. *Carbon disulphide. Cyanogen.* SILICON. *Silicon dioxide.* 104. *Glass.* Give facts relating to the early use of glass. TIN. 105. Symbol, etc. How is lead tested for in tinned iron? 106. Compounds.

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Hydrocarbons and Derivatives.—107. What are the hydrocarbons? How are many of them produced? Name the most important series of hydrocarbons. The most important derivatives.

PARAFFINES. How do they differ in composition? Give general formula. *Methane.* Symbol, etc. What is fire damp? 108. How is the burning of CH_4 shown? *Chloroform. Petroleum. Kerosene. Paraffin.* OLEFINES. 109. How do they differ in composition? Give general formula. *Ethylene.* Symbol, etc. How is its burning shown? AROMATIC COMPOUNDS. How do they differ in composition? Give general formula. *Benzene.* Symbol, etc. *Benzine.* Nitro-benzene. *Aniline.* Aniline colors. Aniline dyes. 110. *Toluodine. Carbolic acid.* ESSENTIAL OILS. Symbol, etc. How is the dissolving of oil of turpentine shown? The solvent action? How is oil of turpentine prepared? 111. Oil of cloves?

CAMPHORS AND RESINS. 111. Common camphor. Common resin. Gum resins. Balsams. Caoutchouc and Gutta Percha. Vulcanized rubber. Hard rubber. Amber. Asphalt. 112. ALCOHOLS. How is the term alcohol used? What is the composition of the alcohols? *Methyl alcohol. Ethyl alcohol.* Symbol, etc. What is proof spirit? ETHERS. What is their composition? *Ethyl oxide.* Symbol, etc. How is its volatility shown? Its combustibility? 113. Sulphuric ether, acetic ether. How may the production of ether be shown? ALDEHYDES AND ACIDS. How are they formed? Acetic aldehyde. *Chloral.* Chloral hydrate.

Carbhydrates.—113. Composition, etc. Name the most important

carbhydrates. SUGARS. *Sucrose.* Symbol, etc. 114. How is crude sugar refined? *Glucose. Amylose.* How is glucose or amylose detected in cane sugar? 115. FERMENTATION. What is fermentation? By what is it caused? What is a ferment? What are the two stages of ordinary fermentation? How is it shown that alcohol is a product of fermentation? What is the action in acetic fermentation? *Alcoholic Liquors.* Wine. Beer. Malt. 116. Diastese. *Distilled liquors.* Brandy. Whiskey. STARCH. Dextrine. CELLULOSE. 117. Gun-cotton. Celluloid. Collodion. GUMS.

Acids.—117. Occurrence. Name the most important organic acids. 118. ACETIC ACID. Symbol, etc. What are acetates? How is the preparation of pyroligneous acid shown? *Vinegar.* OXALIC ACID. Symbol, etc. Name two of the most important oxalates. 119. TARTARIC ACID. Symbol, etc. Cream of tartar. Tartar emetic. Rochelle salt. Rochelle powders. CITRIC ACID. MALIC ACID. TANNIC ACID. SALICYLIC ACID.

Alkaloids.—120. Occurrence, etc. Name the most important alkaloids. Describe each.

Albuminoids.—120. Composition, etc. Name the most important albuminoids. Describe each.

Fats and Fixed Oils.—121. Composition, etc. 122. Give examples of common fats and oils. *Butter. Linseed oil.* What is boiled oil? Printer's ink. Olive oil. Castor oil. Cod-liver oil. Sperm oil. *Glycerine.* Nitro-glycerine. Dynamite. *Soap.*

Coloring Substances.—123. Origin, etc. Name the most important organic coloring substances. Describe each. DYEING. How is a fast color produced? What is a mordant? Name some common mordants. What was the most celebrated dye of antiquity? Where was it found? How is the action of a mordant shown?

APPENDIX.

Apparatus.

Balance and Weights.

A balance sufficiently accurate for the requirements of common chemical experiments may be constructed as follows:

Cut from a sheet of tin a strip $\frac{3}{4}$ of an inch wide and 8 inches long, double it lengthwise, forming a strip of double thickness, bore a hole through the centre of this, and spread apart the sides so as to form a trough. Put a straight wire 10 inches long, and with notches filed in it near the ends, in the trough. Adjust the wire so that it will move endwise with considerable friction by closing the ends of the trough around it, and by binding it to the trough by means of a fine wire through the hole at the centre. The trough and wire form the beam of the balance.

Next drive a sixpenny nail *through* a strip of half-inch board (which may be a foot or more long and two inches wide) so that when the strip is leaned against a wall or other support the nail will project horizontally and be about 6 inches from the base of the support, and reduce, by filing, a section of the upper side of the nail to an edge. This edge is to serve as a support for the beam.

For pans use pieces of tin, $2\frac{1}{2}$ inches square (the small disks in one end of fruit-cans make good pans). Bend two pieces of light wire, each 6 inches long, into a U-shape and solder them to the pans for handles, and attach the handles with heavy thread to the beam wire. Then place the beam on its support, and if it is not horizontal make it so by moving the wire. The balance is now complete.

Metric weights are best adapted to chemical experimenting. Weights of sufficient accuracy may be made as follows: Balance a nickel five-cent piece, which weighs nearly five grams, with a piece of clean copper wire. Mark off the wire into five equal parts and cut off three one-fifth parts for *one-gram* weights and bend the remaining two-fifths part into a V-shape for a *two-gram* weight. Keep the five-cent piece for a *five-gram* weight. Balance a gram weight with a piece of fine wire and cut this into ten equal parts for *tenths of a gram*. These weights, with two additional five-cent pieces, will be found sufficient for all the weighing required in making the experiments in this book. They should be kept in a box. To render the balance more convenient for finding specific

gravities, make also a weight of lead to fit the angle of the trough, that will balance one of the pans when the other is removed. The weights of the body whose sp. gr. is to be found are made by first weighing it in the usual manner, then removing one of the pans, and balancing the beam with the leaden weight, and finally supporting the body by means of the pan thread in water and weighing again.

Fig. 33 shows a balance of the best construction. The beams of such

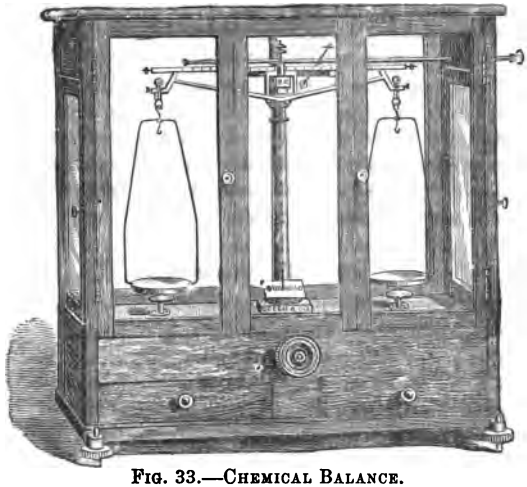

FIG. 33.—CHEMICAL BALANCE.

balances are provided with wedge-shaped fulcrums of hardened steel, called *knife edges*, which turn on polished agate plates, and the beams are graduated for a small movable weight called a *rider*, which is used, in connection with the weights in the pan, to more accurately counterpoise the body which is being weighed.

FIG. 34.—METRIC WEIGHTS.

Fig. 34 shows the weights used with such balances. The gram weight and its multiples are made of brass, and the parts of a gram of platinum.

Metric Measures.

MEASURES OF LENGTH.—The divisions of the metre (39.3685 inches), $\frac{1}{10}$, $\frac{1}{100}$, and $\frac{1}{1000}$ of its length, called respectively the decimetre, the centimetre, and the millimetre, are used in chemistry.

Make a metric rule as follows: Get a strip of wood or pasteboard $3\frac{1}{16}$ inches long. Divide one edge of this into 10 equal parts, and each of these divisions into 10 equal parts. The length of the entire scale will be a *decimetre*, the larger divisions will be *centimetres*, and the smaller ones *millimetres*.

FIG. 35.—METRIC SCALE.

MEASURES OF CAPACITY.—The *litre* (l., a cubic decimetre) and cubic centimetre (c.c.) are common measures. A cubic centimetre of distilled water at 4° C. (39.2° F.) weighs *one gram*. Make a measuring tube as follows:

Select a long, narrow test-tube, support it upright on one of the scale-pans by tying it with a thread to the handle, and balance it with sand. Then weigh 10 grams of water in the tube and divide the part occupied by the water (making an allowance for the curved bottom) into 10 equal parts, making the division marks with a sharp file. Each section of the tube will then measure 1 c.c.

Thermometers.

Thermometers, with the scale marked on the tube or enclosed within an attached tube, and without a case, are required for chemical purposes. The reading of the Centigrade or of the Fahrenheit scale may be converted into that of the other by the following easily derived formulas:

$$C. = \tfrac{5}{9}(F.-32°)\,;\quad F. = \tfrac{9}{5}C. + 32°.$$

Thus 20° C. $= \frac{9}{5} \times 20° + 32°$ or 68° F., and 95° F. $= \frac{5}{9}(95°-32°)$ or 35° C.

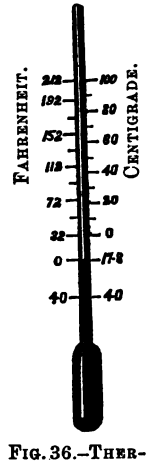

FIG. 36.—THERMOMETRIC SCALES.

Lamps.

For common illuminating gas, which is the best and cheapest burning material for most laboratory purposes, the Bunsen lamp is used. It may be obtained of any dealer in chemical supplies. In the absence of gas, the common alcohol lamp is generally used. An alcohol lamp may be made as follows: Get a common ink or mucilage bottle, and a cork that will fit it loosely. Make a hole through the cork, insert a short metal tube in it, and put several thicknesses of ordinary lamp wick, 3 or 4 inches long, through the tube. Fill the bottle with alcohol, insert the cork, and after the wick becomes wet with the alco-

FIG. 37.—ALCOHOL LAMP.

hol the lamp is ready to light. A tin cap may be made to fit over the mouth of the bottle, to prevent the evaporation of the alcohol.

The *Fletcher burners*, embracing a variety of forms of heating apparatus, and burning either illuminating gas or kerosene, are excellently adapted to many laboratory purposes.

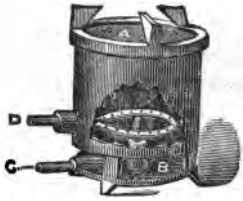

FIG. 38.—LOW TEMPERATURE BURNER.

The "Low Temperature Burner" produces a range of temperatures from warm air to red heat. The "Hot Blast Blow-pipe" (Fig. 39) has a vertical jet, *v*, to be used for the purposes of an ordinary alcohol or gas flame, and a blow-pipe jet, *b*. The tube supplying air is coiled around the gas tube, and both are heated by a flame *f* underneath. The vertical jet works on a hinge, so that it may be used to light the blow-pipe jet.

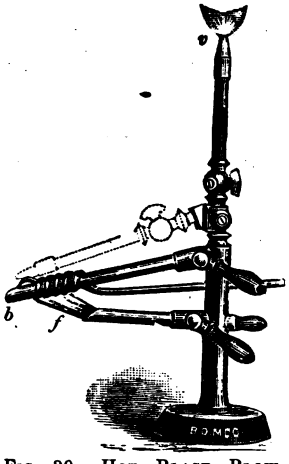

FIG. 39.—HOT BLAST BLOW-PIPE.

A common kerosene lamp may be used for evaporating and other purposes for which low temperatures are required.

Blow-pipes.

A blow-pipe is an instrument for conducting a small current of air into

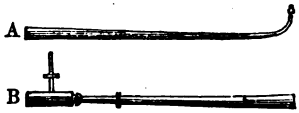

FIG. 40.—BLOW-PIPES.

a flame. A common form of the instrument is a conical tube of brass, 8 or 10 inches long, curved near the smaller end (A, Fig. 40). A blow-pipe may be easily made out of a glass tube. The air current should be produced entirely by the action of the cheeks, and may be made continuous (without being affected by breathing) by a little practice.

Blowers.

The simplest apparatus for forcing air through the blow-pipe is the *hydrostatic blower* (Fig. 41). Two large bottles with tightly-fitting corks, each containing a long and a short tube, are placed at different levels. The long tubes are connected by a piece of rubber tubing, and the short tube of the lower bottle is connected with the blow-pipe in the same manner. The upper bottle is filled with water, which will run into the lower bottle through the siphon formed by the connected tubes, and force the air through the blow-pipe. The water is started by pressure with the mouth through the tube *a*, or by suction through *b*. The blow-pipe should be clamped to an adjustable support. It may be fastened by a curved wire to the ring of the retort stand. An efficient foot-blower is shown in Fig. 42.

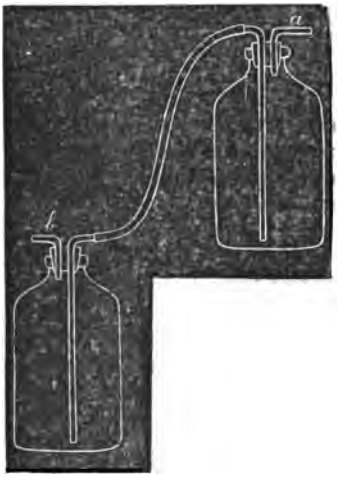

FIG. 41.—HYDROSTATIC BLOWER.

Pneumatic Trough.

A pneumatic trough is a vessel in which gases are collected over water. A common form of the apparatus is an oblong box of metal, wood, or glass, with a shelf resting on the sides for supporting the vessel in which the gas is to be collected. The vessel, if not too large, can be filled with water in the trough and lifted inverted upon the shelf. An ordinary bucket or small tub provided with a shelf answers for a large pneumatic trough. For small receivers, as test-tubes, small bell glasses, etc., a dish about 6 inches in diameter and 3 inches deep, of japanned tin, earthenware, or glass, may be used as a pneumatic trough. A convenient receiver support for such a trough is a tin lid (as that of a candy jar) with a hole in the rim to admit the delivery tube and one in

FIG. 42.—FLETCHER FOOT BLOWER.

the top to admit the gas into the receiver. The receivers cannot generally be filled in a small trough, but may be filled outside, and by carefully covering them with a piece of paper or glass they may be placed on the shelf. Test-tubes may be kept upright on the shelf by means of a ring of lead placed on the rim. A vessel full of gas may be lifted from the trough and the gas be securely retained by placing a saucer or other shallow dish under the vessel and lifting the dish (which will contain some water) and vessel together.

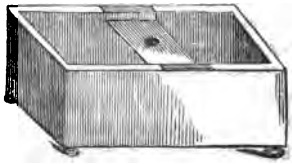

FIG. 43.—PNEUMATIC TROUGH.

Gas-holders.

A large bottle makes a convenient gas-holder for small quantities of gas. One of the bottles of the blower (Fig. 41) may be used for this purpose. Short pieces of rubber tubing, with one end plugged with a short glass rod, or tube sealed at one end, should be provided to close the outer ends of the tubes in the cork of the bottle.

To put gas into the bottle, fill the bottle with water, insert the cork (with its tubes) and put on the stoppers. Then invert the bottle and support it with its mouth under water in a pneumatic trough. This may be done by means of a shelf with a hole 3 or 4 inches in diameter, placed across the top of the trough. Then remove the cork and let it rest on the bottom of the trough, allowing the longer tube to remain partly within the bottle. The gas is then collected by placing the end of the delivery tube in the mouth of the bottle.

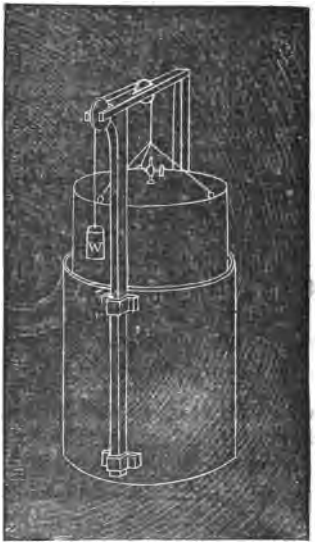

FIG. 44.—GAS-HOLDER.

To transfer gas from the bottle to a smaller receiver, force the gas into the receiver, inverted full of water in the pneumatic trough, as air is forced into a flame.

Another form of gas-holder is shown in Fig. 44. It consists of a cylindrical vessel containing water and a similar vessel inverted in the water. The inverted vessel is lifted

and supported by a weight, W. The vessels should be made of zinc, or galvanized iron. The inner one may be 1 foot in diameter and 2 feet high (of about 12 gallons capacity). The bottom of the inner cylinder, which should be convex outward, has a hole through its centre containing a stop-cock.

To put in gas, open the stop-cock and remove the weight, when the inverted cylinder will sink and become filled with water. Now connect the end of the tube delivering the gas, by means of rubber tubing, with the stop-cock, and attach the weight. The gas replaces the water in the rising cylinder. Extra weights may be added to relieve excessive pressure produced by an increase in the flow of gas. When sufficient gas has been collected, close the cock, remove the tube, and make the weight just sufficient to balance the cylinder.

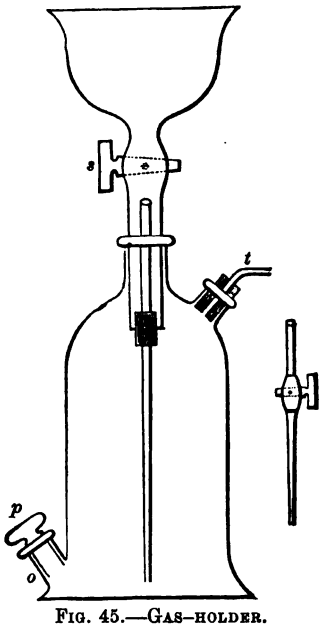

FIG. 45.—GAS-HOLDER.

To transfer gas, connect the stop-cock by a rubber tube with the receiver to which the gas is to be transferred, lessen the weight, and open the cock. A deep bucket, or any vessel of suitable size and shape, may be used for the outer cylinder of this apparatus.

Fig. 45 shows another form of gas-holder. To put gas into it, open the tube *t* and fill the vessel with water through the funnel; then close *t* and the stop-cock *s*, and replace the plug *p* with the tube delivering the gas. As the gas goes in the water goes out through *o*. To transfer gas, close *o*, connect the receiver into which the gas is to be put with *t*, put water in the funnel, and open *s*.

Compressors and Pincettes.

A *compressor* is an apparatus used to check or stop the flow of a liquid or a gas through rubber tubing. A compressor well adapted to regulate the flow of a liquid or gas, also to serve as an efficient stop-cock, is the

screw compressor shown in Fig. 46; one adapted to quickly stop the flow is shown in Fig. 47.

FIG. 46.—COMPRESSOR.

FIG. 47.—COMPRESSOR.

FIG. 48.—PINCETTES.

Pincettes are small brass or steel forceps used for holding objects in a flame.

Retort Stand and Other Supports.

Retort stands are used for supporting vessels over a flame. The rings vary in size and are adjustable on the rod. Beakers, flasks, retorts, and evaporating dishes, unless these vessels are very small, should not be placed in contact with the flame. The *wire gauze* is a piece of gauze from 3 to 5 inches square, made of fine brass wire. It is placed under a vessel to be heated in a flame for the purpose of distributing the heat. The *sand bath* is a shallow, sheet-iron pan, containing sand in which the vessel is placed to be heated. It renders the heat very uniform. The *water bath* is a vessel containing water, on which, as a cover, the vessel containing the liquid to be heated is placed. The heating liquid is by this arrangement kept below a certain temperature.

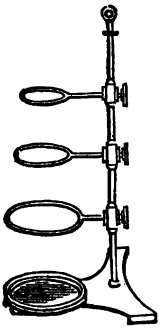

FIG. 49.—RETORT STAND.

FIG. 50.—TRIANGLE.

The *triangle* is an equilateral triangle made of soft iron wire, for supporting small vessels on a ring of an iron stand over a flame.

A good support for round-bottomed flasks is a broad hoop (which

may be cut from a round wooden box) wrapped with a strip of cloth. It should be of a size sufficient to prevent the flask from resting on the centre of the bottom.

Filtering Apparatus.

Filter paper is a porous, unsized paper, freed from inorganic impurities. It is cut into disks called filters, having a diameter a little less than twice that of the funnel in which they are to be used. A filter is generally prepared for use by folding it twice so as to form a quadrant, and then opening it so as to leave three thicknesses of paper on one side and one on the other, thus giving it the form of a hollow cone. It is made to keep its place in and fit the funnel by wetting it with a little water.

For rapid filtration, filters are sometimes folded as follows: First fold the disk as just described, then open the last fold, and the paper will have the form of a semicircle, Fig. 51. Now place the edges, *cb* and *cd*, on the crease, *ce*, and make the creases *cr* and *cv*. Then open the paper and fold each segment, *cdv*, *cve*, etc., so that the four new angles will be opposite the four first formed. A filter thus made, called a *ribbed filter*, touches the funnel only at the alternate creases in the paper.

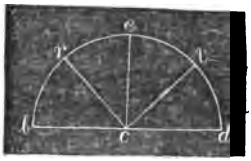

FIG. 51.—TO SHOW FOLDING OF A FILTER.

The funnel is conveniently supported by means of a filter stand, but it may be supported in other ways, as in a ring attached to a shelf, or in the neck of a bottle. A filter should never be quite filled.

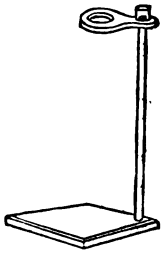

FIG. 52.—FILTER STAND.

Stoppers.

Caoutchouc stoppers, because so compact and closely fitting, are much better than corks for chemical purposes. Corks should be softened by rolling them between two hard surfaces, as with the foot on the floor. They may be rendered much less pervious by soaking them in melted paraffine.

TO REMOVE STICKING GLASS STOPPERS.—Strike the stopper gently with a piece of wood, or against a table, and if this fails to loosen it, heat the neck of the bottle by friction with a coarse string or in the flame of a lamp. The neck expands, and the stopper is generally loosened. If it still sticks, wedge two pieces of wood between the projecting part of the stopper and the

mouth of the bottle, bind their ends together with wire to keep them in place, and invert the bottle in water. The swelling of the wood should force out the stopper.

Cork-Borers.

Cork-borers are hollow cylinders of brass or steel for making holes

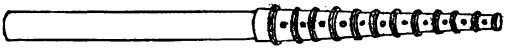

FIG. 53.—CORK-BORERS.

through corks to admit glass tubes. It is convenient to have a set of borers of different sizes. Cork-borers may be made of strong tin tubes with the edges soldered together by filing away the joint until it is of the same thickness as the other part of the tube, strengthening the tube by soldering to the outside of one end a short tin cylinder, and sharpening the other end. The borer is worked by means of a stout wire passed through holes in the end to be held in the hand. In using the cork-borer, the hole should not be cut entirely through the cork from one end, but should be bored from both ends. The end of a glass tube to be put through a cork, should be rounded by heating to redness and cooling, or else with a file or on a grindstone.

Mortars, Evaporators, Crucibles.

A *mortar* is a vessel in which substances are pulverized with a pestle. Mortars are made of porcelain, iron, glass, or agate, the porcelain mortar being in most common use. A heavy tea-cup or bowl and wooden pestle

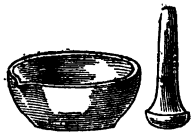

FIG. 54.—MORTAR AND PESTLE.

FIG. 55.—EVAPORATOR.

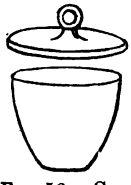

FIG. 56.—CRUCIBLE.

answer very well for pulverizing many substances. Some substances may be crushed with a knife-blade on a piece of glazed paper. Mortars for ordinary purposes should be about 3 inches in diameter.

An *evaporator* is a shallow porcelain (usually) dish in which liquids are heated slowly. A convenient size is 4 oz.

A *crucible* is a small vessel in which substances are heated intensely. Porcelain crucibles are used for ordinary purposes. Convenient sizes are $\frac{1}{8}$ oz. and $\frac{3}{4}$ oz.

Glass Apparatus.

VESSELS IN WHICH LIQUIDS MAY BE HEATED.—Such vessels have very thin bottoms.

Beakers are vessels with a flaring rim, having the form of an ordinary tumbler. They therefore stand upright without support, and their contents may be readily stirred. They are usually sold in sets of different sizes called *nests*. Convenient sizes are 2, 3, and 5 oz.

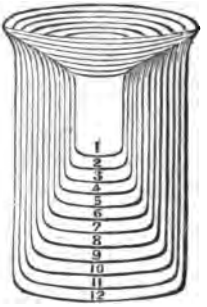

FIG. 57.—NEST OF BEAKERS.

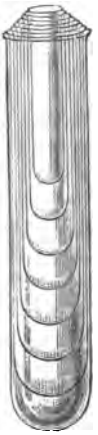

FIG. 58.—NEST OF TEST-TUBES.

Test-tubes are long, cylindrical vessels, convenient for heating a small quantity of substances quickly. They are of various sizes; for ordinary purposes they should be from 4 to 6 inches long and the opening small enough to be closed with the thumb. A few test-tubes of large size may be kept for receivers and generators.

A *test-tube rack* is a wooden stand for supporting test-tubes. Its shelves either contain holes in which the tubes are placed erect (Fig. 59) or posts on which they are inverted (Fig. 60). In an inverted position tubes quickly dry, and their inner sides are protected from dust. A *test-tube holder* is a contrivance for holding a test-tube in the flame. It may consist of two pieces of wood, one of which is hinged to the other, and with a hole between the pieces at the free ends to receive the tube, or of a strip of

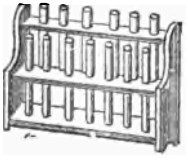

FIG. 59.—TEST-TUBE RACK.

FIG. 60.—TEST-TUBE RACK.

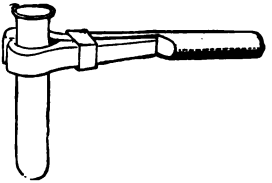

FIG. 61.—TEST-TUBE HOLDER.

several folds of paper placed around the tube. Test-tubes can generally

be held between the thumb and fingers. A convenient *test-tube cleaner* is a short piece of rubber tubing on the end of a glass rod or tube.

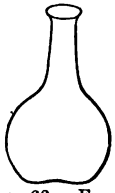

FIG. 62.—FLASK.

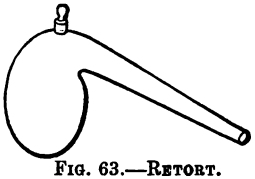

FIG. 63.—RETORT.

Flasks and Retorts.—Flasks are used for a great variety of purposes retorts are used mainly for certain kinds of distillation.

2. VESSELS TO CONTAIN LIQUIDS AND GASES.—Such vessels hav thick walls.

Bottles.—Bottles are either of clear or green glass, narrow or wide-mouthed, have either cork or glass stoppers. Liquid reagents should be kept in narrow-mouthed, glass-stoppered bottles of 6 to 8 oz. capacity. Dry reagents should be kept in wide-mouthed bottles of 1 to 2 oz. capacity. The bottle should be plainly labeled with the name and symbol or formula of the substance it contains.

Receivers.—Receivers are of various forms. Wide-mouthed bottles of clear glass make very good receivers in which to collect and experiment with gases. Open-bottomed receivers may be made of bottles by cut-

FIG. 64.—RECEIVERS.

FIG. 65.—DEFLAGRATING SPOON.

ting off the bottoms (p. 145) Convenient sizes are pint and quart receivers. *Glass cylinders* are frequently used as receivers.

A *deflagrating spoon* is an apparatus used for burning substances in gases. It consists of a small bowl-shaped vessel, to which is riveted a straight wire handle.

Funnels.—Funnels of $2\frac{3}{4}$ and $3\frac{1}{3}$ inches in diameter are of convenient sizes for most purposes. The best angle for funnels for filtration is 60°.

Glass and Rubber Tubing.

Two varieties of glass tubing are used by the chemist, *hard* and *soft*. Hard tubing is very difficult to fuse; it is used for tubes in which to heat intensely or ignite substances. Soft tubing readily softens in an alcohol or gas flame; it is put to a great many uses by the chemist.

FIG. 66.—SECTIONS OF GLASS TUBING.

A, Fig. 66, is a good size for hard, and B for soft glass tubing.

Rubber or caoutchouc tubing is used for connecting glass tubes, for gas and liquid delivery tubes, etc. The inner diameter of the rubber tube must be a little less than the outer diameter of the glass tubes which it is to connect. The ends of the glass tubes should be rounded in a flame to prevent sharp edges from cutting the rubber.

Litmus Paper.

Boil litmus with about six times its weight of water, and filter. Divide the filtrate into two parts; into one stir a few drops of a solution of sodium hydrate, and into the other hydrochloric acid, drop by drop, until the liquid just becomes distinctly red. Now dip strips of filter paper into the blue solution for *blue* paper, and others into the red solution for *red* paper, and dry the strips by suspending them on threads. Litmus paper should be protected from light, and from fumes, etc., of the laboratory. It may be well preserved between the leaves of a book.

Aids in Experimenting.

Glass-working.

CUTTING GLASS.—The best instrument for cutting window or plate glass is the diamond, but as this is expensive, the *wheel-cutter* (kept at hardware stores), a small toothed steel wheel running in the end of an iron handle, answers the purpose very well. Disks may be cut by running the cutter around a bottle or any other round object, or by fastening it to one foot of a pair of compasses, the centre foot being kept from slipping by placing it on a bit of moistened stiff paper laid on the glass.

Glass tubes are cut by means of a triangular file. Make a deep scratch in the tube with the file, one draw of which is generally sufficient. Then take the tube in the two hands, so placed that the thumbs are in contact on opposite sides of the scratch, and break it by pushing with the thumbs and pulling with the fingers.

Tubes larger than about $\frac{3}{8}$ of an inch in diameter cannot be cut by making a single scratch, but must be scratched all around; and success is more certain if the file be wet with spirits of turpentine. Large tubes

may also be easily cut by the method for cutting bottles described in the next paragraph.

Bottles are neatly and quickly cut by wrapping a long piece of twine once around them where the fracture is to be made, pulling the ends of the string backward and forward until the glass is quite hot, and then quickly plunging the bottle into water.

The bottle may be held firmly and the string kept in place by a simple device. A V-shaped opening, like that of a bootjack, is made in a thick pine board about 12 inches by 8, and a piece broad enough to admit the string is cut out of the V end between the sides of the board. The board is clamped in a vise or screwed to a table, and one person holds the bottle in the opening while two others pull the string.

Boring Glass.—A drill for boring small holes in glass may be made by grinding the hard end of a triangular file to a triangular point. First make a scratch where the hole is to be made; then work the drill into the glass, keeping it constantly wet with spirits of turpentine, until the hole is through. Care must be taken in enlarging the hole after the drill is through, as the glass is liable to crack. The drill should be kept sharp by frequent grinding.

A drill for boring large holes is made of a copper tube by filing saw-teeth in one end. Clamp a block of wood containing a hole, in which the drill will easily turn, against the glass, put emery powder and water in the hole and rotate the drill in it, pressing toward the glass. Keep the end of the drill well supplied with emery and water.

Grinding Glass.—Glass is easily ground by rubbing it over an iron plate in wet sand. Any plate with an even surface, as a stove disk, answers the purpose. For very accurate grinding a piece of plate glass and emery-powder (which are kept at hardware stores) are necessary.

Bending Glass Tubes.—Place the tube in the flame so that the section to be bent is just above the extremity of the blue cone, the hottest part of the flame; move it backward and forward a few times in the direction of its length to prevent breaking by the sudden expansion of the glass, and then, holding one end fixed in the left hand, press with the forefinger of the right hand gently upward. The tube will soon begin to bend, and when bent a little, change its position slightly to the right or left, so as to heat it in a new place, pressing upward until it bends a little, as before. Continue this until the required bend is made.

Sealing Tubes.—Hold a piece of glass against the end of the tube to be sealed, in a blow-pipe flame, until the pieces are smelted together; then heat the tube near the joint, and when sufficiently hot, pull a little of the end off with the piece of glass. Hold the pointed

end a short time in the flame to give it a rounded form. Small-sized tubes may be neatly sealed by holding the end in a blow-pipe flame until the opening closes by contraction.

DRAWING OUT TUBES.—Hold the tube between the thumb and first two fingers of each hand in a blow-pipe flame, rotating it constantly until it becomes sufficiently soft to bend easily. Then quickly remove it from the flame and draw the ends apart, continuing the rotary motion, until the diameter has been sufficiently reduced. The conical sections formed by drawing the tube should taper symmetrically. By drawing the sections so far apart as to disconnect them and breaking off the fine points, jet tubes for burning hydrogen, etc., are produced.

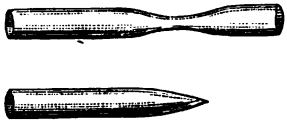

FIG. 67.—DRAWN-OUT TUBE, JET TUBE.

Platinum wires for flame testing should have glass handles, which may be attached to them as follows: Draw off the end of a piece of tubing 2 or 3 inches long, break off the fine point, insert one end of the wire in the opening, and hold the end of the tube containing the wire in the flame. The wire and glass will smelt together.

FIG. 68.—PLATINUM WIRE WITH HANDLE.

PIERCING THE SIDE OF A TUBE.—Direct a small pointed blow-pipe flame against the tube where it is to be pierced, at the same time closing one end with a finger and pressing against the air in the tube with the mouth over the other end. The glass, when sufficiently hot, yields to the pressure and a hole is made. Flasks, test-tubes, etc., may be pierced in the same manner.

BLOWING BULBS.—Seal a tube several inches long, and heat the sealed end, continually rotating the tube, until it is red hot; then, quickly placing the cold end in the mouth, compress the air in the tube, and the heated end will form into a bulb.

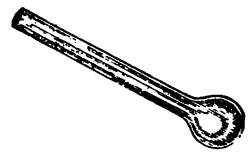

FIG. 69.—GLASS BULB.

FUSING TUBES TOGETHER.—If the tubes are not of the same diameter, heat the end of the smaller one and enlarge it with the end of a file to the size of the larger one. Then hold the ends to be fused together in the flame, not allowing them to touch each other, rotate slowly, and when they are quite soft, remove them from the flame and push them together. To reduce the thickened joint, close one end of the tube, rotate the

joint in the flame, and when sufficiently soft, enlarge it slightly by blowing. Compress it by heating, then blow out again, and repeat these operations until the thickening disappears.

Soldering.

In soldering, a substance is used to cleanse the surfaces to be united, and an alloy to unite them and form a rigid joint. Light articles can be soldered by means of an alcohol or gas flame.

In *soft soldering* a concentrated solution of *zinc chloride* is generally used for cleansing the surfaces. To prepare this, put 2 or 3 g. of sheet zinc, cut into small pieces, in a test-tube, add 10 c.c. of hydrochloric acid, and heat until the action of the acid on the metal has ceased. The solution (zinc chloride) is called *soldering fluid.* The alloy used, called *solder*, consists of lead and tin. Common worn-out pewter spoons and tin-foil are good substitutes for solder.

Brighten the surfaces to be united, wet them with soldering fluid, and clamp them together with a piece of solder between; then heat the joint in a blow-pipe flame. Direct the flame against the metals to be united, and allow them to melt the solder. When the solder has spread between the surfaces, wet the joint with water, and the metals will be found firmly united.

In *hard soldering* borax is generally used for cleansing the surfaces, and a good solder for many articles is silver coin, prepared by hammering a small coin into a thin plate and cutting this into small pieces.

Brighten the surfaces to be united, fit them to each other, and clamp them together. Then moisten the joint with water, and sprinkle it with some pulverized borax; next add the solder, and cover this with borax. Now heat in a blow-pipe flame gently until the borax has ceased to swell, and then intensely until the solder flows between the surfaces. A malleable joint is made by this process.

APPARATUS AND MATERIAL.

Apparatus required in making the experiments in this book ~~once~~ *:*

3 Beakers, 2, 3 and 5 oz.
1 Beaker, tall, 8 oz.
1 Blow-pipe (brass).
2 Bottles, wide-mouthed, quart.
3 " " " pint.
2 " " " ½ pint.
2 Crucibles, porcelain, ⅜ and ¾ oz.
1 Evaporator, porcelain, 4 oz.
1 Filter stand.
1 Flask, 8 oz.
2 Flasks, 4 oz.
2 Funnels, 2 and 4 oz.
1 Funnel tube (small).
1 Triangular file.
1 Glass rod, 6 in. long.
2 feet glass tubing, size of a quill.
1 Glass tube about 1½ ft. long and 1 in. in diameter.
1 Lamp for alcohol or gas.
1 Pneumatic trough, about 10x6x4 in.
1 pair Pincettes (Forceps) steel.
1 Platinum wire, 3 in. long.
1 Receiver, stoppered, quart.
1 " " pint.
1 " " ½ pint.
1 Retort, glass stoppered, pint.
1 " " " ¼ oz.
1 Retort stand.
1 Rubber cork to fit wide-m. pint bottles.
1 Rubber cork to fit large test-tubes.
1 " " " small flask.
3 feet vulcanized rubber tubing adapted to the glass tubing.
2 Test-tubes, 8 in. long.
4 " 6 in. "
6 " 4 in. "
1 Test-tube rack for 12 tubes.
1 wire Triangle.
4 small Watch glasses.
5 or 6 ft. of stout iron wire.
1 square of fine wire gauze, 3½x3½ in.

Chemicals, etc., required in making the experiments in this book once:

Acid, Acetic, ¼ oz.
Hydrochloric, ½ lb.
Nitric, ¼ lb.
Sulphuric, ½ lb.
Alcohol, 2 oz.
Alum, ½ oz.
Ammonia water, ¼ lb.
Ammonium chloride, ½ oz.
" nitrate, ½ oz.
Aniline red, granule.
Antimony, 10 grains.
Arsenious oxide, 5 grains.
Barium chloride, 5 grains.
" nitrate, 30 grains.
Beeswax, ½ oz.
Benzene (Benzol) ½ oz.
Bleaching powder, 2 oz.
Blue vitriol, ¼ oz.
Borax, 10 grains.
Calcium chloride, 1 oz.
Carbon disulphide, ½ oz.
Charcoal, animal, 1 oz.
" common, several pieces.
Cloves, ground, 1 oz.
Cobaltous chloride, 5 grains.
Copper wire, ½ oz.
" filings, ½ oz.
Ether, ¼ oz.
Fluor spar, ¼ oz.
Ferrous sulphide, 10 grains.
Glauber's salt, ¼ oz.
Glycerine, ½ oz.
Gold leaf, sq. inch.
Green vitriol, ¼ oz.
Gun cotton, 5 grains.
Iron filings, ¼ oz.
Lead acetate, ½ oz.
Litharge, 10 grains.
Litmus, 10 grains.
" paper, 1 sheet of each color.
Logwood extract, 15 grains.
Magnesium ribbon, 3 in.
" carbonate, 5 grains.
" sulphate, 5 grains.
Manganese dioxide, 1 oz.
Mercuric chloride, 5 grains.
Mercury, ¼ oz.
" cyanide, 5 grains.
Nut galls, ½ oz.
Oxalic acid, 30 grains.
Phosphorus, 10 grains.
Piano wire, fine, ¼ oz.
Potassium, 5 grains.
" bromide, 2 grains.
" iodide, 2 grains.
" carbonate, ½ oz.
" chlorate, ½ oz.
" dichromate, 5 grains.
" ferreo cyanide, 10 grains.
" hydrate (in sticks) 1½ oz.
" nitrate, ½ oz.
Shellac, 15 grains.
Silver chloride, 5 grains.
" nitrate, 5 grains.
Sodium, 5 grains.
" acetate, 5 grains.
" carbonate, ¼ oz.
" hydrate (in sticks) ½ oz.
Strontium nitrate, 30 grains.
Sulphur, flowers of, ½ oz.
" roll, ½ lb.
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" oil of, 1 oz.
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